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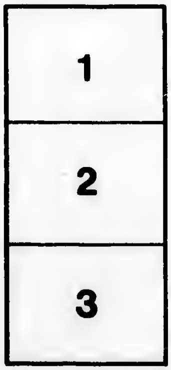
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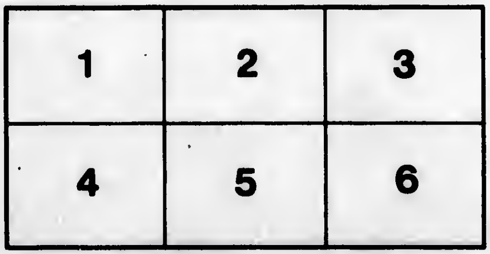
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# MEMOIRS

OF THE

# MUSEUM OF COMPARATIVE ZOÖLOGY

*Compliments of FRANK SPRINGER*
*and*
*ALEXANDER AGASSIZ.*

CAMBRIDGE, U.S.A.
PRINTED FOR THE MUSEUM.
1897.

# MEMOIRS

OF THE

# MUSEUM OF COMPARATIVE ZOÖLOGY

AT

# HARVARD COLLEGE.

VOL. XX.

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CAMBRIDGE, U.S.A.
PRINTED FOR THE MUSEUM.
1897.

UNIVERSITY PRESS:
JOHN WILSON AND SON, CAMBRIDGE, U. S. A.

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Memoirs of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XX.

# THE NORTH AMERICAN

# CRINOIDEA CAMERATA.

By CHARLES WACHSMUTH and FRANK SPRINGER.

IN TWO VOLUMES WITH EIGHTY-THREE PLATES.

Vol. I.

CAMBRIDGE, U. S. A.:
Printed for the Museum.
May, 1897.

To the Memory

OF

LOUIS AGASSIZ,

TO WHOSE INFLUENCE AS TEACHER, EXPOUNDER, AND INVESTIGATOR, NATURAL HISTORY IN AMERICA IS SO DEEPLY INDEBTED,

AND WHO FIRST INSPIRED AND ENCOURAGED US IN OUR EARLIER STUDIES,

This Work

IS GRATEFULLY DEDICATED BY

CHARLES WACHSMUTH.
FRANK SPRINGER.

# NOTE.

The Manuscript of this work in its present form was received at Cambridge for publication September 1, 1894. Although in press ever since then, no part of it has been published until now, and the date of the work, for bibliographic purposes, will be that which appears on the title-page. During the long time that has been consumed in the printing of the plates and letter-press work since the completion of the text, many new species of Crinoids have been described by American authors, among which some of those herein mentioned as new are included, and thus anticipated. No attempt has been made to cover these cases by modifying the text, nor have any questions arising upon publications appearing subsequent to the above date been considered here. In a work of this size while in press changes could not be made to keep pace with current researches, and the date of delivery of the Manuscript for publication was therefore taken by the authors as final, so far as they were concerned.

It is a source of extreme regret that my learned colleague and long-time friend, Dr. Charles Wachsmuth, did not live to see the publication of this Monograph, to which he had devoted so many years of assiduous labor. Never a robust or healthy man, his last few years were almost a continual struggle against disease. His strength gradually failed, and he passed away on February 7, 1896, at the age of sixty-seven years.

Dr. Wachsmuth was a native of Hanover, Germany. He came to the United States in 1852, and soon after engaged in mercantile pursuits at Burlington, Iowa, which became his permanent home. Failing health in time compelled him to relinquish business, and for the last thirty years he applied himself to the study of the Crinoids, first as a recreation and to secure outdoor exercise, and afterwards as his life work, with all the ardor of a scientific devotee. His keen powers of observation, sagacious judgment, and indefatigable energy have left their impress upon the works which have been brought out by us. While his death is a loss to Science not easily repaired, it is to none so great — aside from his family — as to the friend with whom he had worked in pleasant collaboration for so many years. It is with a melancholy pleasure that I avail myself of the opportunity afforded by the appearance of his last work to pay this slight tribute to his memory.

FRANK SPRINGER.

Las Vegas, New Mexico, 1897.

# INTRODUCTION.

The present work is the outgrowth of studies begun over twenty years ago under the encouragement of Prof. Louis Agassiz, and prosecuted continuously ever since. During that time, we made two very large crinoidal collections, of which the original one, in 1873, was secured by Prof. Agassiz, for the Museum of Comparative Zoölogy. Upon this collection one of the writers, while an assistant at the Museum, laid the foundation of the present work. Since 1877 the investigations were conducted by us jointly, and during that time we have built up together the extensive collection which is known as the collection of Wachsmuth and Springer. The advantage of residing, for a time both of us, at Burlington, a locality so well known for the wealth of its crinoidal remains, gave us excellent opportunities to study the Crinoids in all stages of preservation, and being in the field ourselves, we could pick up such material as would help us in the study of minute details.

Since the publication of our first paper on the Crinoids, it has been our aim to direct our special attention to studying the morphology of the various groups as they appeared to us, with a view to future classification, and to revise the work of the previous writers. The various classifications which had been proposed were not based upon strictly morphological principles, and in many cases widely distinct forms were placed together in the same group.

It early became evident to us that we could not hope to gain a correct understanding of the fossil forms except by studying their living representatives. The publication of Carpenter's two Challenger Reports, and De Loriol's important Monograph on the Mesozoic and later Crinoids of France, opened to the working palæontologist a new field of research, and enabled him to study the relations between palæozoic and neozoic Crinoids, which had been altogether misunderstood. It had been the general opinion, ever since the time of Johannes Müller, that all palæozoic forms were widely distinct from the later ones, a view also held by us until 1890.

Before the publication of the first Challenger Report, the attention of palæontologists had been directed almost exclusively to the structure of the dorsal or abactinal side of the calyx; that of the ventral side had been very much neglected, and scarcely any attempt had been made to homologize the plates of the tegmen in the different groups. The first attempt in this direction was made by Wachsmuth in 1877, and the subject was taken up again in our Revision of 1879. Dr. P. Herbert Carpenter discussed the question more elaborately in 1884, when it became manifest that our views differed radically upon several important points, and especially as to the identification of the oral plates. The progress of our studies on this and other questions was published from time to time in the Revision, and in short papers. This was done for the double purpose of making known the results of our own studies, and of stimulating inquiry by others upon points that were still obscure.

Whatever may be the merits or demerits of the Revision — and that the latter are many and serious none are better aware than we — it accomplished one of its purposes. It induced research and provoked discussion upon new lines and with an activity unprecedented in this field. The contributions to the knowledge of the subject, resulting directly from these controversies, have been of incalculable value to us, and none the less so because some of our own theories have been from time to time exploded. As the most important result, it has now become clear that the Crinoids were most intimately connected from the Silurian down to the present time, and that only the Camerata — a highly specialized type — became extinct at the close of the Carboniferous. It was not until this fact was realized that the way was opened to a better understanding of the whole Crinoid group, in which, as so often found in Nature, the simpler forms persisted, and led down to present types. Although it seems plain enough now, it was only by slow steps, and after long and patient research, that this result was reached.

After a large amount of preliminary work had been done, we proceeded to prepare for publication in permanent form such part of it as we could reasonably hope to finish, and to that end we began the preparation of the illustrations in 1887. The work has grown upon our hands to such an extent that we found it necessary to limit it to the Camerata, the largest and most remarkable group among Palæozoic Crinoids. Thus limited, we could hope to give a reasonably full account of this group, and in connection with discussion of the morphological and systematic relations of the other groups, to give some account of the Crinoids generally.

The most of the drawings were made under our personal supervision in our Museum at Burlington; a few were made in Washington. Thirty-five of the plates were drawn by Dr. Charles R. Keyes, the present State geologist of Missouri; thirty-three by Mr. A. M. Westergren, so well known for his drawings for Lovén's great work on the Echinoids; the remaining twelve by Mr. John R. Ridgway, artist for the United States Geological Survey. The execution of the plates occupied about six years, and we avail ourselves of this opportunity to express our thanks to all of these gentlemen for the fidelity and earnestness with which they performed their work.

When the work began to assume a definite shape, Mr. A. Agassiz, on being made acquainted with the extent to which it had progressed, kindly offered to undertake its publication as a part of the Memoirs of the Museum of Comparative Zoölogy at Harvard College. No words of thanks would at all express our sense of the obligation under which this has laid us, not merely for the facility of publication through so desirable a medium, but for the mark of appreciation which this offer implies. If the work shall be found sufficiently useful to science to merit, even in a small degree, the indorsement thus given, we shall deem it the best return we can make.

During the studies that led up to this Monograph, we enjoyed the privilege of continued communication with our lamented friend, P. Herbert Carpenter, up to the time of his decease. We had some energetic controversies in print, and a far greater number in private correspondence that never saw the light. To his incisive and suggestive mind is due the overthrow of more than one promising but untenable theory; and we take a melancholy pleasure in recording here our appreciation of his high attainments, and our sense of the great loss which Science has suffered through his untimely death.

It has been our purpose to give descriptions of all American species of the Camerata known up to this date, and those that could be recognized have been described anew, with the aids derived from the material brought to light since the original descriptions were made. Many of the species were defined from very imperfect specimens, and often without illustrations. In the latter cases we have, when practicable, figured the type specimen, and when necessary and possible have given figures of additional specimens.

During the preparation of the work we have had access to most of the type specimens in the United States and Canada, which were placed in our hands for comparison, study, and illustration. A few only of Prof. Hall's types in the New York State Cabinet of Natural History at Albany, and some of S. A. Miller's later species, we were unable to procure.

Not the least of the pleasure we find in bringing our work to a conclusion, is the opportunity it affords us of acknowledging our obligations to the men of science and collectors of America, for their liberality and personal confidence shown to us, by placing in our hands — often for indefinite periods — original, unique, and priceless collections, without the use of which this work would have been impossible. It would be difficult to express in fitting terms of acknowledgment the full measure of our indebtedness to them, and we can only venture the hope that they may find in the work itself some small return for the valuable contributions they have made toward it.

To Mr. Agassiz we owe a lasting debt of gratitude: first of all for his personal encouragement and valuable counsel, and next for the use of the magnificent collection of the Museum of Comparative Zoölogy. This has been placed at our disposal without restriction, not only for examination at Cambridge, but for removal to Burlington of all specimens we desired, with liberty to use them as if they were our own. Only those who are acquainted with the character and value of this unrivalled collection can appreciate our obligation for such a use of it. It contains the original collection of De Koninck, of the Belgian Carboniferous Crinoids, and the Schultze collection from the Devonian of the Eifel, — by far the finest collections that have ever been made of the rare Crinoids of those interesting localities. There are also the collections made by Hon. B. J. Hall, Prof. W. H. Barris, and the original collection of Wachsmuth, all from the Burlington limestone, which include the types of a large number of the species described by Hall, White, and Meek and Worthen. In addition to these is the fine collection made by C. B. Dyer, from the Hudson River group, of Cincinnati, containing many types of species described by Meek in the Ohio report, besides most excellent material from Waldron, Crawfordsville, and other celebrated localities of the West; also the Walcott collection from New York.

A full account of the various collections made use of by us would exceed the limits of a preface, but we cannot refrain from making particular mention of some of them: —

The collections in the American Museum of Natural History at New York, containing many of the type specimens of the New York Palæontological Reports, have been at all times accessible to us through the courtesy of Prof. R. P. Whitfield, who has been prompt to send us such specimens as we needed for illustration or comparison, and to give us any desired information obtainable from the extensive material under his charge.

During the lifetime of Prof. Worthen, the eminent Director of the Illinois Geological Survey, and afterwards under the administration of his accomplished successor, Dr. Josua Lindahl, we enjoyed the privilege of unrestricted facilities in the use of the type and other specimens in the State Museum of Natural History at Springfield. The private collection of Worthen, containing a large number of the types of the earlier species described in Hall's Iowa Reports, was packed up and inaccessible while he held the position of State Geologist; but after his death, when the collection was acquired by the State of Illinois and incorporated in the State Museum, we were permitted through the courtesy of Dr. Lindahl to examine it, and were given full use of the valuable type specimens. As a mark of our personal esteem, and in justice to the memory of this pioneer collector and geologist, we have inserted the name of Worthen in the notation of such of his type specimens as are now in the State Collection. These types are of great value, as they are the only types of the early Burlington and Keokuk species still in existence, so far as we know, with the exception of a few in the Shumard collection. We have been unable to obtain any information as to the types of Owen and Shumard's descriptions in the Report for Iowa, Wisconsin, and Minnesota, in 1852,—the first Subcarboniferous Crinoids described from the West. A considerable part of the collections made during the first Iowa Geological Survey are said to have been destroyed by fire, either at Burlington or Keokuk, and it is supposed that a number of type specimens were lost in this way. McChesney's types were all lost in the great Chicago fire.

The collections in the Canada Survey Museum at Ottawa, containing the types of all of E. Billings's Lower Silurian species, and the later ones of Whiteaves, have been freely open to us under the authority of Sir Alfred Selwyn, and through the unremitting courtesy of Prof. J. F. Whiteaves.

Through the attention of Dr. C. A. White and Prof. C. D. Walcott, we obtained the use of the types of some of Meek's descriptions in the National Museum at Washington.

Prof. S. H. Williams of Ithaca, New York, had the goodness to furnish us for examination the types of species described by him, from the Museum of Cornell University, and some of the types from the Colonel Jewett collection.

Through Prof. A. H. Winchell we had the use of the specimens in the collection made by Dr. White, now in the University Museum at Ann Arbor, containing the types of a number of well known Subcarboniferous species.

To Dr. G. Hambach of St. Louis we owe the facility of examining the type specimens in the Shumard collection at the Washington University.

We are under special obligations to Prof. Borden, of Borden Institute at New Providence, Indiana, for the opportunity of examining the original collection of Dr. Knapp, of Louisville, from the now exhausted Bear Grass locality near Louisville, containing some of the types of species described by Lyon, Shumard, and Yandell, which now form a part of the Museum of the Borden Institute.

To Prof. S. Calvin we are indebted for the loan of fine specimens from the Hamilton of Iowa and New York, from which we made descriptions of several species.

Our thanks are also due to Prof. W. H. Barris, of Davenport, Ia., who gave us the use of his type specimens and other valuable material from the Hamilton group of Iowa and Michigan, which were under his charge in the Museum of the Davenport Academy of Science.

We also avail ourselves of this opportunity of expressing our high appreciation of the favors extended to us by Dr. G. Lindström, of the National Museum of Sweden at Stockholm, in which are deposited the magnificent collections of Crinoids from the Upper Silurian of Gotland that formed the basis of Angelin's descriptions. Not only has he at all times allowed us the privilege of having special drawings made from unique specimens in the Museum, but on one occasion, on learning of the difficulty under which we labored from want of adequate material to study the genus *Crotalocrinus*, he sent us, without solicitation, a series of specimens, including some of Angelin's originals, with liberty to retain them as long as might be necessary for the examination we desired to make.

We have also to acknowledge our indebtedness to Mr. Walter R. Billings, of Ottawa, Canada, for the loan of types of Trenton species in his own collection, and also for his good offices in securing for our use the collections of Messrs. Stewart and I. F. Sowter. Besides this, Mr. Billings has from time to time furnished us valuable notes in relation to many rare and interesting forms, often illustrated by exquisite drawings from his own hand. We extend our thanks to Mr. John Stewart and Mr. I. F. Sowter, of Ottawa, Canada, for the use of their specimens,—Mr. Stewart having at one time sent us his whole collection for study.

To the owners of private collections in the United States our obligations are so numerous and varied that we cannot attempt to express in proper terms of appreciation our indebtedness to each one.

It is especially difficult for us to express our obligations to Mr. Victor W. Lyon, of Jeffersonville, Ind., who with the utmost liberality placed his own collection at our disposal, and also that of his father, the late Major Sidney S. Lyon, through which we secured the use of all the types of the species described by Major Lyon himself, and by Lyon and Casseday.

Mr. Lisbon A. Cox, of Keokuk, Ia., gave us access to his extensive and unique collection from the Keokuk limestone, containing the types of a large number of species described by Worthen in Vol. VII. of the Illinois Reports.

Mrs. Yandell, of Louisville, Kentucky, has sent us for examination some rare types in the collection of the late Dr. L. P. Yandell. We tender our special thanks to this venerable lady for the efforts she made to serve us.

To the naturalists and collectors of Cincinnati and vicinity we are indebted for great facilities in studying the crinoidal fauna of the Lower Silurian of that region. Mr. I. H. Harris, of Waynesville, Ohio, placed at our disposal the species of his magnificent collection of Hudson River Crinoids. Mr. S. A. Miller favored us with the loan of his valuable types of Lower Silurian species. Mr. E. O. Ulrich, of Newport, Ky., has sent us for examination the types of his species, and besides other instructive specimens. He also used his influence in our behalf with Messrs. Oeh and Vaupel, who placed some of their finest specimens in our hands.

Dr. E. N. S. Ringueberg, of Lockport, N. Y., has sent us the types of his species of the Niagara group of Western New York, with liberty to use them as we might find desirable.

To Prof. J. M. Clarke, of Albany, N. Y., we are indebted for the use of valuable type specimens from the Hamilton group of New York, then in his private collection, but since passed into the New York State Cabinet.

Mr. Thomas A. Greene, of Milwaukee, Wis., placed in our hands a large collection of natural casts from the Niagara group, including types of the Waukegan species; and Mr. W. C. Egan, of Chicago, a similar collection from near Chicago, containing the types of the species described from that locality.

Mr. F. A. Sampson, of Sedalia, Mo., gave us the use of his collection, containing the types of a large number of species described by S. A. Miller in the Missouri and Indiana Reports; and Prof. R. R. Rowley, of Louisiana, Mo., furnished us the types of his species.

We are also indebted for the use of specimens and friendly acts in various ways to Mr. Asa S. Tiffany, of Davenport, Dr. C. C. Washburn, of Waldron, Ind., Dr. Moses Elrod, of Hartsville, Ind., Rev. H. Herzer, of Berea, Ohio, Rev. John Davis, of Louisiana, Mo., Mr. D. H. Todd, of Kansas City, Mo., Mr. G. M. Nickels, of Sparta, Ill., Mr. E. Brown, of Belfast, N. Y., and others.

To Dr. Horace G. Griffith, formerly of Burlington, now of Philadelphia, we express our grateful acknowledgments for his intelligent and unremitting efforts to aid us in the prosecution of this work, and for his steadfast devotion to our interests manifested upon every occasion.

We also bear in kindly remembrance our former townsman, Mr. James Love, whose fine collection was always at our disposal, and which, together with one made by Mr. J. W. Giles, afterwards passed into our hands.

Dr. Charles R. Keyes has at all times exhibited a lively interest in the progress of our work, and we owe to him not only the procurement of some valuable specimens, but other friendly offices.

Nor do we forget our good friend, Orestes St. John, whose keen eye and rare judgment, and no less his skilful pencil, have always been at our service. We have from him some unsurpassed structural drawings, and he presented us several unique Crinoids from the Coal Measures of Kansas.

Our thanks are due to Mr. Wm. F. E. Gurley, of Danville, Ill., for the use of specimens from Waldron, and to Mr. A. C. Benedict, of Indianapolis, for the use of specimens obtained by him at St. Paul, Ind.

In addition to the facilities above mentioned, we have had during the preparation of this work our own collection, which contains authentic specimens of nine-tenths of the species of Crinoids described from the United States, and two-thirds of all the European species. From many of the typical localities we have been able to obtain, either by purchase of local collections, or by personal exertions, large series of specimens, by means of which it has been possible to study in many cases, and among different genera, the individual variation existing in the limits of a species, and the modifications due to growth.

In looking over the descriptions it will probably surprise some of the authors to find so many of their species placed in the synonym lists, but we were obliged to do so after careful study and comparison with authentic specimens.

CHARLES WACHSMUTH.
FRANK SPRINGER.

Burlington, Iowa, May 1, 1894.

Received at Cambridge, September 1, 1894.
ALEXANDER AGASSIZ.

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# CRINOIDEA CAMERATA OF NORTH AMERICA.

## INTRODUCTORY PART.

### I. HISTORICAL.

THE first reference to Fossil Crinoids, according to De Koninck, was made by Agricola in the second half of the sixteenth century. He distinguished between *Trochites*, *Entrochus*, and *Encrinus*. The former name he applied to all detached stem-joints; *Entrochus* to a series of joints, and *Encrinus* to the calyx of *Encrinus liliiformis*, at that time the only Crinoid in which a crown had been found in connection with the stem. As early as the seventeenth and eighteenth centuries the crinoidal remains received the attention of a large number of writers, some of whom regarded them as plants, others as animals.

Rosinus, who lived at the beginning of the eighteenth century, was the first writer to show that the Crinoids were not plants, as before then generally supposed, but were closely related to the Asterids, and especially to the group which afterwards received the name Euryale. He also supposed that the Trochites and Entrochites were parts of *Encrinus*, and not independent bodies.

An important advance in the knowledge of the Crinoids was made by Guettard,* who described the first recent Stalked Crinoid that ever came to Europe. He gave this species, which was afterwards known as *Pentacrinus caput-medusæ* Lamk., the popular name "Palmier marin," and took it to be the type of all fossil Crinoids with pentagonal stem, as opposed to those with a round stem, of which he thought the living type had not been discovered. He gave a moderately fair description of its structure; but added

* Mémoire sur les Encrinites et les pièrres étoilées, dans lequel on traitera aussi des Entroques. (Mém. de l'Acad. Roy. Soc. de Paris, 1755 (published 1761), pp. 224–318.

little as to the systematic position of the Crinoids generally, stating, howev , that they were neither Polyps nor Starfishes.

Linné, throughout all the editions of his "Systema Naturae," placed the Crinoids among the corals. Blumenbach* has the credit of having been the first writer who ranked them with the Asteroids and Ophiurids among the order "Vermes crustacei," which corresponds approximately to our present Echinoderms. Lamarck, in the first edition of his "Système des Animaux sans vertèbres," published in 1801, ranged them among the "Polypes à rayons coralligènes," along with Gorgonia, Umbellula, and Pennatula; but he afterwards modified this opinion, and in 1812† referred the Crinoids to the "Polypes flottants," which he arranged next to the Radiata. In 1816‡ he placed the Encrinites (Stalked Crinoids) among the Polyps, but the Comatulæ (Free-floaters) among the Echinoderms. Schweigger§ directed attention to the close resemblance that he found to exist between the arm structure of stalked Crinoids and Comatulæ, and he considered the two forms to be closely related. Cuvier in 1817,‖ and again in 1830,¶ placed the Crinoids among the Echinoderms.

The name "Crinoidea," with the rank of a family, was proposed in 1821 by J. S. Miller, for the lily-shaped, radiate animals which theretofore had been known as *Encrinites* and *Pentacrinites*. He restricted the group to the Brachiate forms, and to those provided with a stem, as appears by the following definition: ** "An animal with a round, oval or angular column, composed of numerous articulating joints forming a cup-like body containing the viscera, from whose upper rim proceed five articulated fingers." This description includes neither Blastoids nor Cystids, which were placed by Miller's successors as subordinate groups under the Crinoids. It also excludes the Comatulæ and the genus *Marsupites*, which have no stem, and which probably for this reason were referred by him to the "Stelleridæ." Among the latter he recognized four divisions: "Comatulæ, Euryale, Ophiura, and Asteria," and he placed *Marsupites* in the same group with Euryale. Miller knew little of the structure of the Comatulæ, but enough

* Handbuch der Naturgeschichte, 1780.

† Extrait du cours de Zoölogie du Muséum d'histoire naturelle sur les Animaux sans vertèbres, etc., 1812.

‡ Histoire naturelle des Animaux sans Vertèbres, etc., 1815–1822.

§ Handb. der skeletlosen, ungegliederten Thiere, Leipzig, 1820, p. 528.

‖ Le Règne animal, 1817 (1re), Vol. IV., p. 12.

¶ Op. cit. (Ed. of 1830.)

** A Natural History of the Crinoidea, Bristol, 1821, p. 7.

to be struck by the resemblance they bear to the crown of *Pentacrinus*, and he pointed out that the pentagonal plate at the base of the subglobose body of the Comatulæ occupies the position of the first column joint of the "Crinoidea."

Miller subdivided the Crinoidea into four groups: the ARTICULATA, to which he referred the genera "*Apiocrinites, Encrinites* and *Pentacrinites;*" the SEMIARTICULATA with "*Poteriocrinites;*" the INARTICULATA with "*Cyathocrinites, Actinocrinites, Rhodocrinites*, and *Platycrinites;*" and the COADUNATA with "*Eugeniacrinites.*" His primary groups were based upon the mode of union between the stem and calyx, and between the latter and the arms; his genera upon the number and arrangement of the plates in the dorsal cup. Considering that in 1821 only about twenty-five species of Stalked Crinoids, recent and fossil, were known, and many of them only from fragmentary specimens, we cannot help admiring the genius of Miller, who brought order out of chaos, and laid the foundation of the present classification of the Crinoidea. His genera have been generally accepted, and are now recognized as the types of well-marked families.

Miller introduced an elaborate terminology, but unfortunately did not always apply his terms to the same parts. In some of his genera he gave the term "pelvis" to the proximal ring of the plates within the calyx, in others to the plates of the ring above. In *Apiocrinus* and *Actinocrinus* he called the radials "first costals;" the succeeding ones "second costals," and the first axillaries "scapulæ." In *Platycrinus*, however, and in *Poteriocrinus* and *Cyathocrinus*, the radials are his scapulæ, and are followed by arm plates. *Platycrinus*, according to Miller, has no costals at all; but in the dicyclic *Cyathocrinus* and *Poteriocrinus* costals are said to be represented by the plates of the interradial basal ring.

A year after the appearance of Miller's work, Schlotheim published the first part of the Supplement to his Petrefactenkunde,* reproducing therein Miller's figures together with his own, and adopting his generic and specific names. A year later, however, in the second part of that work, he withdrew Miller's generic names, and referred all Stalked Crinoids back to *Encrinus* and *Pentacrinus* respectively.

Goldfuss in his great work † adopted Miller's classification and terminology. Cumberland ‡ did not consider Miller's name "Crinoidea" appro-

* Nachträge zur Petrefactenkunde, 1822–1823 (2 Bände, mit 37 Kupfer-Platten).

† Petrefacta Germaniæ, Düsseldorf, 1826–1833.

‡ Reliquiæ conservatæ, Bristol, 1826.

priate, as not a single *Encrinus* or *Pentacrinus* resembled in the smallest degree a lily, either in stem, root, flower, or bud. Nor did he think it absolutely proved that they were animals instead of coraline sensitive plants.

In 1825, Say * described three new species under the genus *Pentremites*, which he made the type of a new family of the Crinoidea, and proposed for it the name Blastoidea. He also described the genus *Caryocrinites*, which he took to be intermediate between *Cyathocrinus* and *Actinocrinus*. In the same year two additional species of *Pentremites* were described by G. B. Sowerby.

In the years following up to 1840, a number of new species of Crinoids were described by Mantell (1822), Pander (1830), Steininger (1831, 1837, and 1838), Goldfuss (1832 and 1838), Zenker (1833), Phillips (1835–1836), F. A. Roemer (1836 and 1839), Heisinger (1837), Sedgwick and Murchison (1837), D'Orbigny (1837), Münster (1838–1846), and others; but they added little to the general knowledge of the Crinoids.

L. Agassiz, in his Prodrôme d'une Monographie des Radiaires ou Echinodermes,† referred the Crinoids to the "order" *Stellerides*, together with the "genera" *Comatula* and *Marsupites*, which, as he stated, differ from the Crinoids only in not having a stem.

J. V. Thompson, in 1836, discovered ‡ that the small species, which he had described in 1827 as *Pentacrinus europæus*, loses its stem at a more advanced stage of growth, and changes into a free-floating Comatula. Thompson also discovered the ovaries along the pinnules.

Other important discoveries in relation to the anatomy and development of recent Crinoids were made by Adams, Heusinger, Savigny, Delle Chiaje, Blainville, and Dujardin. D'Orbigny in 1839 described the remarkable recent genus *Holopus*,§ a Crinoid not attached by a jointed stem, but by the lower end of the calyx.

In 1840 appeared the classical work of Johannes Müller, "Ueber den Bau des Pentacrinus caput-medusæ," ‖ which marked a new era in the history of the Crinoidea, and threw a flood of light upon the whole group. Müller in this work discussed the relation between the Pentacrinites and Comatulæ, and pointed out the anatomical differences in the structure of Crinoids and

* Journ. Acad. Nat. Sci. Phila., Vol. IV., pp. 292–296.
† Mémoires de la Société des Sciences Naturelles de Neufchatel, 1835, Tom. I, p. 168.
‡ Memoir on the Starfish of the genus *Comatula* (Edinburgh New Philos. Journ., Vol. 20, p. 295.
§ Wiegmann's Archiv für Naturgeschichte, I, p. 185, Taf. 5, Figs. 2–7.
‖ Read before the Berlin Akademie der Wissenschaften, April 30, 1840.

Asterids. He also introduced a more rational terminology for the plates of the calyx, which is still used by Zoölogists and Palæontologists. He proposed the name "*Basalia*" for the pelvis plates of Miller, and "*Radialia*" for Miller's scapulæ and costals, including the first axillary. When the rays are free above the first radial, the axillary supports the arms; but when that plate forms a part of the calyx, it is followed by the "*Distichalia*," and these by the "*Palmaria*." For the supplementary plates he introduced the terms "*Interradialia*, *Interdistichalia* and *Interpalmaria*."

Müller divided the Crinoids into three great groups: the "*Crinoidea Articulata*," the "*Crinoidea Tessellata*" and the "*Crinoidea Costata*," which he defined, and of which he gave a list of the principal genera.

Of the *Articulata*, to which Müller referred *Pentacrinus*, *Apiocrinus*, *Encrinus*, and the Comatulæ, he said that the rays develop directly from the base of the calyx, and the lower ray plates are united laterally by a skin, which is either naked or paved with irregular plates; that this skin is continued to the ventral disk, closing the ventral side of calyx and arms; and that the radials consist of three successive plates, of which the first and second, and the axillary and the first arm-joint, are united by muscles.

Müller's Tessellata combine Miller's "Semiarticulata," and "Inarticulata," and include the Blastoidea, Cystidea and the Cretaceous genus *Marsupites*. The calyx is composed of 3, 4 or 5 basals, which are sometimes separated from the radials by a ring of "parabasals." Between the radials there may be "interradials," and between the distichals and palmars, "interdistichals," and "interpalmars." The "Scheitel" (ventral disk) covers the whole ventral surface; it is constructed of solid plates, united at their edges.

The Tessellata were subdivided by Müller into two groups: Crinoidea *with arms*, and Crinoidea *without arms*. To the former he referred all true Crinoids and the Cystid genus *Caryocrinus*, forms having no separate anal opening and no "Tentakelfurchen" (food grooves) upon the disk, and none probably upon the arms. The *armless* Crinoids comprise the "Pentremites" (Blastoidea) and "Sphaeronites" (Cystidea), forms with separate mouth and anus.

Müller's classification, although a great advance upon that of Miller, was not accepted by the French and English writers succeeding him; but it was revived later on by Ferd. Roemer and von Zittel.

In 1842 a classification was proposed by Thos. Austin and Thos. Austin

Jr.,* who made the Crinoidea in the widest sense a class of the Echinodermata, to which they gave the name "Pinnastella." Among the latter they placed as orders: —

I. *CIONACINETI* (Stalked Crinoids).
Families: Apiocrinoidea.
Poteriocrinoidea.
Encrinoidea.
Pentacrinoidea.
Marsupiocrinoidea.
Platycrinoidea.
Actinocrinoidea.
Dimerocrinoidea.

II. *LIBERIA* (Free-floaters).
Gnathocrinoidea.
Astracrinoidea.
Comastella.

Only the Platycrinoidea and Poteriocrinoidea † were defined.

To the former they referred the genera: *Platycrinus, Dichocrinus, Hexacrinus, Caryocrinus,* and *Cyathocrinus;* to the latter: *Poteriocrinus, Symbathocrinus, Extracrinus,* and *Pentacrinus.* Their Encrinoidea include: *Encrinites, Eucalyptocrinites, Cupressocrinites,* and *Euryocrinites;* their Marsupiocrinoidea: *Marsupiocrinites* and *Crotalocrinites;* the Actinocrinoidea: *Actinocrinites, Rhodocrinites, Melocrinites* and *Tetracrinites.* The Austins placed the Blastoidea with the Sphaeroidocrinoidea, and the Periechinidæ under the Columnida.

D'Orbigny in 1852 ‡ undertook to subdivide the Crinoids (including Blastoids and Cystids) into twelve families, which contain most heterogeneous elements. For description he divided the plates of the calyx into zones, without reference to their radial or interradial position.

The next classification was that of Ferd. Roemer, who wrote in 1855, § and divided the Crinoidea into three great groups: —

I. *Actinoidea*, or true Crinoids, having large, pinnule-bearing arms.

II. *Cystidea*, Crinoids in which the arms are feebly developed or wanting, and mouth and anus are separate.

III. *Blastoidea*, Crinoids without arms, the soft parts of the animal enclosed within a calyx, which is closed from all sides, leaving only a few openings.

The *Actinoidea* embrace:

A. The Astylida, Actinoidea, Crinoids without jointed column.
- a. *Attached by the lower face of the calyx.*
  Holopocrinidæ and Cyathidiocrinidæ.
- b. *Calyx free.*
  Astylocrinidæ, Marsupitidæ, Saccocomidæ, and Comatulidæ.

* Ann. and Mag. Nat. Hist., first series, Vol. X., pp. 108 to 109.
† Recent and Fossil Crinoids. Thos. Austin and Thomas Austin, Jr, London, 1843.
‡ Cours élémentaire de Paléontologie, II.
§ Lethaea geognostica (Ausgabe III.), 1855, pp. 210-285.

B. Stylida, Crinoids with a jointed column.

a. *The tegmen formed of a skin.*

Pentacrinidæ, Apiocrinidæ, Eugeniacrinidæ, Encrinidæ, Cupressocrinidæ, Cyathocrinidæ.

b. *The ventral surface covered by heavy plates, immovably united.*

Poteriocrinidæ, Rhodocrinidæ, Platycrinidæ, Actinocrinidæ, Melocrinidæ, Ctenocrinidæ, Sagenocrinidæ, Anthocrinidæ.

c. *The arms imperfectly developed.*

Haplocrinidæ and Gastrocomidæ.

Roemer's families are natural groups, except his Cyathocrinidæ, among which he united a number of widely different forms. But this is partly due to Miller, who had included with *Cyathocrinus* forms which were afterwards referred even to different orders. Roemer, believing that Miller's typical species, *Cyathocrinus planus* was a *Poteriocrinus*, made his second species *Cyathocrinus tuberculatus*, which Phillips in 1843 had made the type of *Taxocrinus*, the type of *Cyathocrinus*.

Together with the Classification was published Roemer's classical memoir on the Cystidea and Blastoidea, of which especially that of the latter furnished most valuable additions to our knowledge of the morphology of that group.

In 1845 appeared the Memoir of Leopold von Buch on the Cystidea. He gives excellent descriptions of several genera, and places the group at equal rank with the Blastoidea and Crinoidea.

De Koninck and Le Hon, in 1853,* described a number of new species from the mountain limestone of Belgium, and proposed certain changes in the terminology of the calyx plates. The proximal ring of plates he calls "basals," whether the species is monocyclic or dicyclic; those of the second ring in dicyclic forms "sous-radiales." The radials comprise all plates up to the first axillary; and the succeeding plates of the rays, when parts of the calyx, are "articles brachiaux," otherwise arm plates. The term "interradiales" is applied only to the plates of the four regular sides; those of the posterior side are "pièces anales."

Another classification was brought out by Pictet, in 1857,† who divided the Crinoids into nine families. The first and ninth of his families contain almost exclusively Neozoic forms. The former embraces the *Comatulæ* and *Marsupites*, to which was added the Palæozoic *Astylocrinus* (*Agassizocrinus*);

* Recherches sur les Crinoides du Terrain Carbonifère de la Belgique.

† Traité de Paléontologie, par F. J. Pictet, Paris, 1857, Tom. V., pp. 278–345.

the latter family, to which he applied the name "Pycnocrinidées," is divided into four Tribus, — the "Eugeniacriniens, Encriniens, Apiocriniens, and Pentacriniens." His second and third families comprise "Blastoides" and "Cystidées;" the remaining ones, the "Tessellata" of Müller.

It is somewhat curious that Pictet, while placing *Cupressocrinus*, *Eucalyptocrinus*, and *Crotalocrinus* each in a separate family, referred all the other Palæozoic Crinoids to only two families, — the "Haplocrinides" and "Cyathocrinides." His Haplocrinides embrace *Haplocrinus*, *Coccocrinus*, *Ceramocrinus*, *Myrtilocrinus*, *Epactocrinus*, and *Gasterocoma*; all the other Palæocrinoidea were placed under the Cyathocrinides. It is difficult to understand upon what ground Pictet's families were based. His "Polycrinides," with *Eucalyptocrinus*, have closer affinities with *Melocrinus* and *Dolatocrinus* than these with *Cyathocrinus*; while *Cupressocrinus* agrees closer with the Haplocrinides than many of the Cyathocrinides among themselves.

Pictet subdivided the Cyathocriniens into four tribus, — the "Cyathocriniens," the "Actinocriniens," the "Carpocriniens," and the "Platycriniens," — of which the first are dicyclic, the last monocyclic; while the Actinocriniens and Carpocriniens are in part monocyclic and in part dicyclic. He did not discriminate between genera in which the lower brachials form part of the calyx and those in which they are free, nor did he pay the least attention to the presence or absence of anal plates.

The classification of Pictet, although not so satisfactory as that of Roemer, was accepted by Dujardin and Hupé.* The latter, however, changed the sequence of the families, making the "Cystidées" the first family, and placing the "Comatulides" last.

In America, up to 1858, little attention had been paid to the study of Crinoids. Of the fourteen hundred American species that are now described, only about seventy were then defined. In 1843 and 1851, Hall had described a moderate number from the Silurian in the Palæontology of New York, Vols. I. and II., and a few additional ones through the Regent's Reports at Albany. Owen and Shumard, in 1852, United States Geological Report of Wisconsin, Iowa, and Minnesota, described nineteen species from the Subcarboniferous of the Mississippi Valley, mostly from the Burlington group; and Shumard, in Swallow's Missouri Geological Report of 1855, twelve species from the same horizon. The few remaining species had been described by Conrad, Roemer, Casseday, and Yandell and Shumard.

* Histoire Naturelle des Zoöphytes Echinodermes, par M. F. Dujardin et M. H. Hupé, Paris, 1862.

About the year 1858 the interest of the American Palæontologists was aroused by remarkable discoveries of Crinoids in the Southern and Western States. Troost, at the meeting of the American Association for the Advancement of Science, in 1850, reported the acquisition of eighty-six new species, with sixteen new genera, from the State of Tennessee.* This discovery, however, was totally eclipsed by the wonderful finds in the Northwest, where, at Burlington alone, upwards of three hundred species were obtained, which for beauty and excellence of preservation surpassed anything that had ever been seen before. This one locality furnished a greater number of species than had been described from America and Europe together up to 1857; and while before, with a few exceptions, only calices had been obtained, now hundreds of specimens were found in which arms, stem, and occasionally the root, were preserved. The collections which were made at that time by Wachsmuth, Barris, Dr. Thieme, and Hon. B. J. Hall, of Burlington, and which were afterwards secured by Prof. L. Agassiz for the Museum of Comparative Zoölogy, give testimony to the energy and enthusiasm with which collecting was carried on in those days. The same interest, often mingled with jealousy, was manifested by the men of science, who, anxious to publish the new forms, and fearing they might be preceded by competitors, brought out preliminary descriptions to secure priority for their species. These descriptions, in many cases, were so indefinite that the identification of the species was almost impossible, and this created considerable annoyance and labor to later writers.

About the same time other large deposits of Crinoids were discovered in Indiana. Crawfordsville furnished upwards of thirty species, Waldron and Hartsville nearly twenty. At the latter places large collections were made by Dr. Moses N. Elrod and Dr. C. C. Washburn. At Louisville and surrounding country a large number of new species were found by Lyon, Yandell, and Dr. Knapp; at Keokuk, Iowa, by Dr. Kellogg, who afterwards discovered also the rich Crinoid bed at Richfield, Ohio. Still more successful as a collector in the Keokuk rock was L. A. Cox, who found two local deposits of finely preserved Crinoids, — one at Keokuk, the other at the opposite side of the river, which produced nearly forty new species. Dr. Roeminger discovered the Crinoid bed in the Hamilton group at Alpena, Michigan; Springer that of Lake Valley, New Mexico, in the Burlington

* These genera and species were described by Troost in a monograph. The manuscript was deposited at the time of his death in the Smithsonian Institute, but was never published, and he did not receive the credit which is probably due to him.

group. Among the pioneer collectors must be mentioned also Mr. Anthony, U. P. James, and C. B. Dyer, of Cincinnati; I. H. Harris, of Waynesville; J. Kelly O'Neall, of Lebanon, Ohio; Thomas A. Greene, of Milwaukee; W. C. Egan, of Chicago, — who all made large local collections which have furnished many type specimens.

Within the last ten years three most remarkable finds were made in the West: — the first at Le Grand, near Marshalltown, Iowa, in the Kinderhook group; the second on Indian Creek, ten miles from Crawfordsville, Indiana, in the Keokuk group; and the other in the Upper Coal-measures at Kansas City. The Le Grand bed furnished about twenty-three new species, not counting the Blastoids. Of the latter, two species of *Orophocrinus* are represented, and in quite a number of their specimens the stem and pinnules are preserved. Most of the Crinoids have arms and stems, and some of them roots. The crinoidal layer, which is but an inch or two thick, furnished many excellent slabs. We have one in our cabinet about a yard in diameter, on which ninety-five specimens are exposed, both sides of it being thickly studded.

The Indian Creek locality was discovered by the late Charles S. Beachler while collecting for us. It proved to be a local deposit in the bed of the creek, not over twenty feet in diameter, and covered over a foot deep by water. Too much credit cannot be given to Mr. Beachler, who obtained under the most trying circumstances several thousand specimens, represented by nearly forty species. The specimens in places were so plentiful that more than half of them had to be sacrificed to save the others. The preservation is excellent, and in some respects surpasses that of any other locality.

The bed at Kansas City is in the heart of the city. It was discovered by Sidney J. Hare in the excavation for a large building. Only seven species of Crinoids were found, but they are of exquisite beauty, and being embedded in a soft clay, are of most excellent preservation. Good collections were made here by David H. Todd, Sidney J. Hare, S. A. Howe, and E. Butts.

Almost as fast as new discoveries were made the species were described, and in 1865 the number of American Crinoids had increased to six hundred species. In 1858 appeared the Iowa Report, Vol. I., by James Hall, in which he described over ninety species of Crinoids, not counting the Blastoids, and in the following year, in a Supplement to that Report, seventy-four additional ones. In 1861 Hall issued a paper entitled "Description of

New Species of Crinoidea, Albany, 1861," in which he gave on eighteen pages preliminary notices of one hundred and eleven species. A large number of these descriptions remain in that shape to this day, while some of the species were redescribed by him in the Boston Journal of Natural History, Vol. VII. In the Palæontology of New York, Vol. III., Hall described twenty-six species from the Helderberg groups, — some of them, however, from arm or stem fragments, — and from eighty to ninety additional ones through the different Annual Reports of the New York State Museum.

A large number of species were described by Meek and Worthen, and after Meek's death by Worthen; they amount to two hundred and seventy species, with ten new genera, all well illustrated. Another lot was described by Lyon and Casseday, and by Lyon individually; in all thirty-one species, with six new genera. Dr. C. A. White described thirty-five species, and made three new genera. In Canada, E. Billings described some forty species from the Trenton and Hudson River groups, with seven new genera. In later years the most prolific species-maker was S. A. Miller, who increased the number of species quite considerably. Many of his species have proved to be synonyms, and while some of his new genera will be accepted by every writer, others will go into oblivion. Additional species were described by Whitfield, Wetherby, Ulrich, Barris, S. H. Williams, Whiteaves, Ringueberg, Wachsmuth and Springer, Walter R. Billings, Keyes, Rowley and Hare, and others.

The American Palæontologists followed the terminology of De Koninck, and their descriptions, as a rule, are concise and readily understood. But few writers besides ourselves discussed morphological questions, and S. A. Miller, Prof. Chapman, and we, are the only ones who attempted to classify the Crinoids.

Billings, like most of the earlier writers, believed that the opening in the disk of Palæozoic Crinoids represented mouth and anus combined.* He pointed out that the grooves and galleries, passing out from the centre of the disk at the inner floor, are connected with the ambulacral system, and communicate through the arm openings with the arm grooves, but do not enter the tegminal aperture, which he found to be interambulacral. When Billings took up this question again in 1869,† presuming that the aperture represented the mouth, he concluded that in the earlier Crinoids, in Blas-

* Geol. Surv. of Canada; Decade IV. pp. 14 to 17.

† Notes on the Structure of the Crinoidea, Cystidea and Blastoidea (Amer. Journ. of Sci. and Arts (2d series), July, 1869, and January and September, 1870.

toids and many Cystids, the mouth was disconnected from the ambulacra; and that in those Cystids in which more than one opening is represented, the lateral one is the mouth, and not the central one, as had been generally supposed.

A different interpretation of the opening was given by Schultze, Sir Wyville Thomson, Dr. W. B. Carpenter, Dr. Lütken, Lovén and Wachsmuth, who maintained that the mouth of all Echinoderms was located in the centre of radiation, and insisted that the interambulacral opening was the anus. Schultze * could not understand how a Crinoid with an interambulacral mouth could be sufficiently provided with food, even if the arms were prehensile organs, which they were not. He stated that Billings's important discovery, that the ambulacra enter the mouth by the arm openings, left but little doubt that the mouth of the older Crinoids was subtegminal and central; that the food entered the body through the arm openings, and was carried underneath the tegmen to a common oral centre. His views were corroborated by Meek,† who saw Wachsmuth's famous specimen (Pl. V., fig. 10), and found the ambulacral tubes intact beneath the tegmen. These observations were confirmed by Wachsmuth,‡ who had discovered additional specimens with the ambulacra preserved, and most instructive natural casts, in which the course of the ambulacra is indicated by ridges upon the surface.

In England, for a long time, very little attention was paid to the study of fossil Crinoids, and many well known forms are undescribed to this day. Among the earlier English writers were Mantell, Cumberland, Parkinson, Phillips, McCoy, Sedgwick, and the Austins. Their descriptions in many cases are so primitive that neither genera nor species can be identified. They were followed by the writings of Rofe and Grenfell, and those of Dr. P. H. Carpenter and F. A. Bather, whose excellent work attracted the attention of every earnest student of Crinoids, and opened a new era in the history of palæontological research. In France but little work was done upon Palæozoic Crinoids. Oehlert described a number of interesting Devonian forms, and among them several new genera. De Loriol, so well known for his Monographs on the Crinoids of Switzerland and France, directed his attention exclusively to Neozoic forms.

* Monogr. Echinod. Eifl. Kalk., Wien, 1867, p. 7.

† Notes on some points in the Structure and Habits of the Palæozoic Crinoidea, by F. B. Meek and A. H. Worthen (Proc. Acad. Nat. Sci. Phila., 1869, p. 323).

‡ Amer. Journ. Sci. and Arts, Vol. XIV., August, 1877.

In Germany the principal writers on fossil Crinoids were: Goldfuss, Müller, the two Roemers, Münster, Steininger, Sandberger, Quenstedt, Beyrich, Schultze, v. Meyer, v. Zittel, Follman, Walther, Kunisch, Wagner, Steinmann, Neumayr, and Jaekel. The Belgian Crinoids were described by de Koninck, and by Fraipont; those of Russia by Eichwald, Grewingk, Volborth, F. Schmidt, and Trautschold; a few Indian specimens by Waagen, and those from Australia by Etheridge, Jr., and McCoy.

In the year 1879 appeared the first volume of von Zittel's Handbuch der Palæontologie, with a chapter on the Crinoids. He made the latter a class of the Echinodermata, with three orders: the *Eucrinoidea* or Crinoidea *sensu stricto*, the Blastoidea and Cystidea. The Eucrinoidea were divided into three suborders: *Tessellata*, *Articulata*, and *Costata*, in which he followed Müller. His Tessellata were separated by him into twenty-six families, which comprise all the Palæozoic forms, and the Cretaceous genera *Marsupites* and *Uintacrinus*; the Articulata into seven families, all Mesozoic and recent forms; the Costata comprise only the Jurassic *Saccocoma*.

The *Tessellata* were defined by him as having thin, immovable calyx plates, united by suture with smooth faces; "interradials" rigid; mouth subtegminal and anus excentric. Among the families he discriminates between forms in which the tegmen consists:—

A. Exclusively of five large orals, or in addition to them small covering pieces closing mouth and food grooves. The orals forming a pyramid or a so-called *Consolidations-Apparat*." Arms simple: *Haplocrinidæ*, *Pisocrinidæ*, and *Cupressocrinidæ*.

B. Tegmen composed of small plates; the mouth closed by five orals, which either are tegminal, or placed underneath the tegmen; the anus excentric. Dorsal cup formed of three (rarely two) zones; the base generally dicyclic. Arms strongly developed; their ambulacra covered by two or three pieces: *Hybocrinidæ*, *Cyathocrinidæ*, *Taxocrinidæ*, *Ichthyocrinidæ*, *Crotalocrinidæ* and *Cheirocrinidæ*.

C. Tegmen ventricose or balloon-shaped, composed of numerous thin pieces; mouth subtegminal. Anal tube long and heavy, the anal opening near the base. Arms strongly developed and pinnule-bearing: *Heterocrinidæ*, *Poteriocrinidæ* and *Marsupitidæ*.

D. Tegmen composed of heavy, frequently nodose plates; the middle portion covered by seven larger pieces. Mouth subtegminal, communicating with the arms through plated tubes. Anus often extended into a long proboscis with the opening at the upper end: *Gasterocomidæ, Platycrinidæ, Carpocrinidæ, Briarocrinidæ, Dimerocrinidæ, Barrandeocrinidæ, Actinocrinidæ, Stelidiocrinidæ, Melocrinidæ, Polypeltidæ, Uintacrinidæ, Glyptocrinidæ* and *Rhodocrinidæ.*

E. Tegmen bottle-shaped, narrower at the top; composed of large, polygonal plates, regularly arranged. Arms not extended beyond the calyx, biserial; placed between rib-like projections, or occupying closed compartments: *Calyptocrinidæ.*

The *Articulata* were defined by Zittel as follows: Plates of the dorsal cup generally very heavy, the articular faces excavated or smooth. Base monocyclic, and formed of five pieces; exceptionally dicyclic. Tegmen, as a rule, composed of a skin-like perisome, rarely plated; mouth and food grooves exposed. The mouth central; anus excentric; orals present or absent. Plates of the dorsal cup perforated by axial canals, passing out from the dorsal organ, and continued along the solid parts of the arms to the ends of the pinnules.

To the *Articulata* he refers the following families: the *Encrinidæ, Eugeniacrinidæ, Holopidæ, Plicatocrinidæ, Apiocrinidæ, Pentacrinidæ* and *Comatulidæ.*

Examining the characters upon which Zittel separated the Tessellata from the Articulata, it appears that not one of his distinctions holds good throughout the families of either group. The "Taxocrinidæ" and "Ichthyocrinidæ," which he refers to the Tessellata, have a more flexible disk than either the Encrinidæ or Apiocrinidæ, and even than many of the Pentacrinidæ; and, besides, have an open mouth and open food grooves. The Poteriocrinidæ have a flexible disk, and well defined muscular articulations between the radials and costals. The interbrachials of *Guettardicrinus* and *Apiocrinus roissyanus* are as heavy and rigid as those of any *Actinocrinus*, and the plates of the dorsal cup in *Eupachycrinus* and *Erisocrinus* are perforated by axial canals, a character which was supposed to occur only among the Articulata. Neither is it true that the Articulata are "rarely dicyclic"; the reverse would be more nearly correct, for most of them had small infrabasals in early life, which gradually fused with the stem. No doubt Zittel's groups marked A and E form excellent divisions, but B, C, and D comprise widely differing types, and some of their families include monocyclic and dicyclic forms. As a whole, Zittel's classification marks a great advance over those of his predecessors, and he is the first writer who gave a good definition of the families, and who arranged them systematically.

In 1879, a month or two after the appearance of von Zittel's Handbuch, we published Part I. of our Revision of the Palæocrinoidea, embracing the Ichthyocrinidæ and Cyathocrinidæ; and in 1881 Part II., containing the Sphæroidocrinidæ. In both parts we gave a review of the genera then known, which were redescribed and systematically arranged. We also gave with each genus a list of the species and their synonyms so far as then known. No effort was made by us to subdivide the three groups, because, as we thought, the knowledge of fossil Crinoids had not been advanced sufficiently to justify it. We waited for the publication of the Challenger Report, which we hoped would solve certain important morphological questions. It seemed to us that a revision of the genera, many of which had been incorrectly, others insufficiently, defined, and the arranging of them systematically among a few large natural groups, was preferable to a classification based upon unreliable data. We separated the Crinoids into Palæocrinoidea and Stomatocrinoidea,* the latter to include all Mesozoic and later forms.

The name "Palæocrinoidea" had been introduced by Wachsmuth in 1877 as a subdivision of the Crinoidea,† to include those forms in which the disk is roofed by a second integument, which he supposed to exist in all Palæozoic Crinoids. He recognized among the Palæocrinoidea three different plans: —

A. The *Actinocrinus* plan: Tegmen rigid; composed of heavy, rather large, immovable plates, forming a free arch.

B. The *Taxocrinus* plan: Tegmen flexible, consisting of minute, movable, plates.

C. The *Cyathocrinus* plan: Tegmen at the four regular sides composed of a large interradial plate, the posterior side extended into a tube or sac; mouth and food grooves covered by small plates.

The differentiations in the tegmen he thought were accompanied by important modifications in the composition of the dorsal cup, and he expressed the opinion that the construction of the tegmen afforded excellent characters for subdivisions. These divisions were actually made by us in the Revision, Part III., and they form practically the foundation of our present classification, notwithstanding that our views respecting the tegmen itself have since then undergone considerable changes.

* In place of Stomatocrinoidea we afterwards adopted Carpenter's preferable name "Neocrinoidea."

† His paper "On the Construction of the Summit and its Value in Classification." — Amer. Jour. Sci. and Arts (3d series), Vol. XIV., September, 1877.

Among the questions discussed by us in Part II., the most perplexing one was that respecting the orals. As these plates are developed among the first in the larva, it seemed to follow that they must be present also in the Palæocrinoidea; but the difficulty was to determine which of the various plates in the summit represent them. The median portion of the tegmen in most of those Crinoids is covered by from seven to ten asymmetrically arranged, more or less prominent plates, consisting of a central one of larger size, four others nearly as large directed anteriorly, and five others placed posteriorly. We regarded the central plate as an element unknown among the later Crinoids, which occurred only in forms with a closed mouth, and that it actually covered the oral opening. The orals, we thought, were represented by six plates: four large and two smaller ones, the two latter jointly representing the posterior oral, broken up on account of anal plates.

Part III. of our Revision appeared in 1885. It contains the genera which had not been considered before; and we also completely revised Parts I. and II., making important changes in the classification. The Palæocrinoidea were subdivided into three sub-orders: the CAMERATA, the INADUNATA, and the ARTICULATA, which we distinguished by the mode of union between the plates of the calyx, and the condition of the arms, whether free above the radials, or partly incorporated into the cup. The origins of these groups date back to a time of which we have no palæontological record, they being already highly differentiated among the earliest known Crinoids. We divided them into twenty-six families.

The *Crinoidea Camerata* were separated into Reteocrinidæ, Rhodocrinidæ, Thysanocrinidæ, Glyptasteridæ, Melocrinidæ, Actinocrinidæ, Platycrinidæ, Hexacrinidæ, Eucalyptocrinidæ, Barrandeocrinidæ, and Acrocrinidæ.

The *Crinoidea Articulata* were subdivided into Ichthyocrinidæ and Crotalocrinidæ.

The *Crinoidea Inadunata* were subdivided into; — A. *Crinoidea Larviformia*, with Haplocrinidæ, Cupressocrinidæ, Gasterocomidæ, and Stephanocrinidæ; B. *Crinoidea Fistulata*, with Hybocrinidæ, Heterocrinidæ, Anomalocrinidæ, Belemnocrinidæ, Cyathocrinidæ, Calceocrinidæ, Catillocrinidæ, Poteriocrinidæ, Encrinidæ, and Astylocrinidæ.

Most important from a morphological point of view was the discovery of a fixed law respecting the orientation of the stem, which enabled us to ascertain the presence of infrabasals in many species in which these plates are hidden by the column. By means of this law we were led to the conclusion that by far the majority of the Neocrinoidea are built on the dicyclic plan, and either have small infrabasals, or had them in their larval state. We continued to use the term "vault" as opposed to disk, believing that the tegmen of Palæozoic Crinoids differed morphologically from the disk of later ones. Respecting the oral question our views had undergone considerable changes, owing to the discovery that the two smaller plates, which we supposed represented together the posterior oral, are radially disposed instead of interradially, and we inferred that the central plate alone represented the oral pyramid of other Crinoids, a view afterwards strongly contested by Dr. P. H. Carpenter.

In 1884 Carpenter's Challenger Report on Stalked Crinoids came out, and in 1888 that on Comatulæ. In the former the author discussed among other things the morphological relations between Palæozoic and Mesozoic forms, and replied to some points which we had brought out in the Revision. With regard to the structure of the tegmen he argued that some Platycrinidæ had a "vault"; but that the ventral covering of others did not differ essentially from the disk of the Neocrinoidea. He believed that the Palæozoic Crinoids differed essentially from the later ones by means of their irregular symmetry, caused by the introduction of anal plates; and upon this and other grounds, to which we allude in another place, he made the Palæozoic and later Crinoids independent orders. In his classification he fell back upon Leuckart's almost forgotten name "Pelmatozoa," which he made a branch of the Echinodermata, with Crinoidea, Blastoidea, and Cystidea as classes, and the Palæocrinoidea and Neocrinoidea as orders. He also discussed the oral question, adopting the view which we had brought out in 1881, but abandoned in the following year. He assumed that the so-called central plate represents the dorso-central at the abactinal side, the six proximals (his orals) the basals, and that the latter are homologous with the genitals of the Urchins. In the second Challenger Report, that on the Comatulæ, we were criticised very severely for asserting that probably the Comatulæ had infrabasals in the larva, which were actually discovered by Bury before the Report was published.

Among the many interesting papers written by Dr. P. H. Carpenter, none attracted more attention than the one in which he discussed the relations of the basals in monocyclic and dicyclic Crinoids.* He proved that

* On the "Oral" and Apical Systems of Echinoderms (Quart. Journ. of Microsc. Sci., 1878, pp. 351–383).

the proximal ring of the latter represents an independent element, and that their second ring of plates corresponds morphologically to the proximal one in monocyclic forms. This is now accepted by almost every writer. Another important contribution to the knowledge of Crinoids was made by a paper on *Allagecrinus*,* a Carboniferous genus, in which the ventral surface is covered completely by five oral plates, thus retaining persistently the structure of the *Antedon* larva.

The progress in the knowledge of fossil Crinoids was paralleled by that among recent ones, of which a great number of new forms were obtained by the dredging expeditions. Until about 1860 we possessed of Stalked Crinoids only a few specimens of *Pentacrinus caput-medusæ*, and one or two of *Holopus Rawsoni;* but since then new discoveries followed in rapid succession. In 1864, Sars described the genus *Rhizocrinus*; Jeffreys, in 1872, a new species of *Pentacrinus* from the Bay of Biscay; de Pourtalès, in 1874, a second species of *Rhizocrinus*. The dredgings by the "Blake" under the supervision of A. Agassiz in the Gulf of Mexico brought to light the new Comatulid genus *Atelecrinus*, and a large number of specimens of *Pentacrinus;* those of the "Albatross" in 1891, off the Galapagos Islands, the remarkable genus *Calamocrinus*. The largest results, however, were obtained by the "Challenger" expedition, which produced three new genera of Stalked Crinoids, and one of Comatulæ. Progress in morphology and embryology in later years has been as rapid as the discovery of new species; in proof of which we need only refer to the works of Allman, Goette, Sars, Greeff, Ludwig, Pourtalès, Bell, Barrois, W. B. Carpenter, Wyville Thomson, Perrier, Bury, P. H. Carpenter, Vogt and Yung, and A. Agassiz.

The oral question was finally solved in 1888 † by our discovery of the remarkable specimen of *Taxocrinus*, which proved conclusively that in forms with large plates around the oral centre, asymmetrically arranged, the orals are represented not by the central plate alone, as we had supposed, nor by the four large and two smaller proximals, as claimed by Dr. Carpenter, but by the so-called central plate together with the four large proximals; the disturbance in the arrangement of the plates being due to the introduction of anal plates. It was further proved that in specimens in which the whole

* On Allagecrinus, the Representative of a new family, etc. By P. H. Carpenter and R. Etheridge, Jr. (Ann. and Mag. Nat. His., April, 1881, pp. 281–297).

† Discovery of the Ventral Structure of Taxocrinus and Haplocrinus, and Consequent Modifications in the Classification of the Crinoidea; by Charles Wachsmuth and Frank Springer (Proceed. Acad. Nat Sci. Phila., 1888, pp. 337–361).

tegmen consists of five large pieces, as in *Haplocrinus*, etc., these plates are orals, and not supplementary pieces as we had supposed.

The logical consequences of these conclusions were taken up by us in 1890,* when we undertook to prove that the so-called vault of Palæozoic Crinoids is not a structure *sui generis*, but a highly differentiated disk; that their large, rather regularly arranged interbrachial and interambulacral plates represent morphologically the smaller irregular pieces between the rays and ambulacra of later forms, and that the Palæozoic and Neozoic Crinoids do not differ so essentially from one another as we had supposed. It also appeared that neither the closure of mouth and food grooves, nor the presence of anal plates, is a constant character among the older Crinoids, and we were compelled in 1888 to abandon the Palæocrinoidea and Neocrinoidea as systematic groups.

That the two groups could not be upheld, was proved also by Neumayr,† who claimed that none of the characters by which they had been separated was persistent; and he proposed in place of them a primary division based upon the condition of the mouth and ambulacra, whether *subtegminal* or *suprategminal*, viz.:

I. *Hypascocrinoidea.* Mouth, ambulacral vessels, and Saumplättchen (the latter if present) beneath the tegmen.

1. *Sphæroidocrinacea.* Cup mostly, tegmen always, constructed of a large number of plates immovably connected among themselves. Generally several of the arm plates incorporated into the calyx by means of interradial pieces. Tegmen roofing the whole ventral surface. Among its plates are readily distinguished a central one, and four and two interradial proximals. Anus either directly piercing the tegmen, or placed at the terminal end of a plated tube. (This group agrees with our Camerata.)
2. *Haplocrinacea.* Cup and tegmen composed of a small number of immovable pieces. The former having but one radial, and no interradials except an anal. Tegmen with a central plate. (Our Larviformia.)
3. *Ichthyocrinacea.* Cup and tegmen composed of very numerous, somewhat movable pieces; the former having two basal rings and more than one order of radials. (Our Ichthyocrinidæ.)

II. *Epascocrinoidea.* Ambulacra not covered by the tegmen; their furrows exposed or closed by Saumplättchen.

1. *Cyathocrinacea.* Base generally dicyclic. Cup without interradials at the four regular sides. Tegmen, so far as known, composed of five orals, which support at their edges the ambulacra; the latter covered by Saumplättchen. Anus within the ventral sac. (Our Fistulata.)

* Perisomic Plates of the Crinoids (Proceed. Acad. Nat. Sci. Phila., October, 1890, pp. 345–375).

† Die Stämme des Thierreiches, Wien und Prag, 1889, pp. 438–460.

2. *Pentacrinacea.* Calyx with a well defined basal ring; infrabasals wanting or rudimentary. Ambulacral furrows and mouth (in all of them?) exposed. Tegmen pliable with movable Saumplättchen, or with five large orals and without Saumplättchen. (Pentacrinidæ, Apiocrinidæ, Plicatocrinidæ, Bourguetocrinidæ, Eugeniacrinidæ, Holopidæ, and Comatulidæ.)

Neumayr's primary divisions are partly based upon incorrect observation. Among the three groups which he refers to the Hypascocrinoidea, the Saumplättchen are subtegminal only in the Haplocrinacea. In the remaining groups they may be subtegminal or exposed among species of the same genus. The Ichthyocrinacea even have an open mouth and open food grooves. On the oral question he agreed with Carpenter, and took the six proximals to be representatives of the orals.

Neumayr ranked the Crinoidea, Blastoidea, and Cystidea as independent classes, and believed that the two former are derived from the Cystidea, which to some extent combined the characters of the three groups.

Dr. Steinmann * adopted our classification of 1885, with Palæocrinoidea and Neocrinoidea as primary groups.

Two other classifications were proposed in America, — one by Prof. E. J. Chapman, the other by S. A. Miller. The former † is to a large extent hypothetical, being founded upon characters of which nothing, or almost nothing, is known among Palæozoic Crinoids. His classification is based mainly upon the presence or absence of a canaliculation within the calyx and arm plates for the occupation of axial cords. He recognizes three leading divisions: —

I. *Emedullata.* Calyx plates and arm plates without internal canals.

II. *Fistulata.* Arm plates with dorsal canal. Calyx plates imperforate.

III. *Canaliculata.* Calyx plates traversed from the basals upwards by delicate radiating canals. The arm plates canaliferous dorsally.

The classification of S. A. Miller ‡ may perhaps facilitate elementary studies, but has no value from a morphological point of view. In forming his families he made the number of basals the most important character for division, next the presence or absence of "subradials," and after this the structure of the "azygous side and other parts." His classification is a reminiscence of that of Angelin, § who divided the Swedish Crinoids into

* Elemente der Palæontologie, Leipzig, 1888.
† A Classification of Crinoids, by Professor E. J. Chapman, Toronto, 1882.
‡ American Geologist, Vol. VI., 1890, pp. 275–286, and pp. 340–357.
§ Iconogr. Crinoid. Sueciæ, 1878.

Trimera, Tetramera, Pentamera, and Polymera. The fallacy of this plan is well shown if we consider that the smaller number of basals is simply the result of anchylosis of two or more of the original five plates; and that in many cases it brings together the most diverse forms, while forms which naturally belong together are widely separated. We need only refer to the highly differentiated Calceocrinidæ, of which some species have four basals, and others but three. In the genus *Platycrinus* the normal number is three; but in many cases they are anchylosed into a solid disk, leaving no trace of suture lines. Under Miller's classification many species, and often individuals of the same species, would have to be referred to different families.

The most important recent European writings on Palæozoic Crinoids are those of Mr. F. A. Bather of the British Museum, who has done much valuable work in systematizing the terminology. His descriptive work has been chiefly confined to the Fistulata of the Wenlock limestone of England, and its equivalent in Sweden; but we should like to see it extended to include the Carboniferous Crinoids of England, of which careful study is greatly needed. His admirable Monograph on the Crinoidea of Gotland, Part I.,* arrived too late to be considered in this work as fully as would be desirable; in it, however, he has rendered a great service to all students by bringing order out of the confusion in which the splendid Swedish collections had become involved by reason of Angelin's fictitious illustrations and restorations. We hope nothing will occur to prevent the completion of his work.

* "The Crinoidea Inadunata," with ten photographic plates, published by the Royal Swedish Academy of Sciences.

## II. TERMINOLOGY.

THE following terminology may be regarded as the result of a two years' correspondence with the late Dr. P. H. Carpenter, carried on with a view to securing greater uniformity and precision in the morphological nomenclature of the Crinoids; and we mutually agreed to adopt it in our future writings. On some points, Dr. Carpenter defined his own position in a paper which appeared about a year before his death.*

Mr. F. A. Bather, in 1890, also † agreed to accept this terminology with very slight modifications, and applied it practically in his earlier descriptions of British fossil Crinoids, but renounced it in 1892, ‡ and proposed in its place a new one, which will be discussed later on. Many of the terms which are explained below are familiar to every student of Crinoids; but as some of them have been used in different senses by different authors, we include them for the sake of completeness. A few of them are new; others, though used by foreign authors, have never been introduced in American Crinoid literature. We believe that the terms are adapted equally well for the description of recent and fossil Crinoids, pinnulate as well as non-pinnulate. There are a few additional terms, not of such general application, which will be found explained in their proper places.

The Crinoids, Blastoids and Cystids, with perhaps a few exceptions, differ from all other Echinoderms in being at some stage of their life provided with a stem for attachment to other objects. This structure gives rise to a difference in habit, by which they live upon the aboral side, instead of creeping about mouth downward in search of food.

The skeleton or test of a Crinoid consists of the *stem* or *column*, and the *crown*. If the stem is provided with lateral appendages, these are called *cirri*. Those of the distal end are the *radicular cirri*, and form the *root*. The stem is constructed of the *stem joints*, of which the larger, and all cirrus-

* "On some Points in the Anatomical Nomenclature of the Echinoderms;" Ann. and Mag. Nat. Hist., 1890 (July number).

† British Fossil Crinoids; ibid. (April number), pp. 306 to 330.

‡ Suggested Terms in Crinoid Morphology; ibid. (January), pp. 51-66

bearing ones, constitute the *nodal* joints, and those interposed between them the *internodal* joints. The term *dorsocentral* is used for the enlarged terminal joint of the stem, by which the young Crinoid is attached to other objects; and *centrodorsal* for the modified, cirrus-bearing top joint of the Comatulæ, as well as for the plate within the infrabasal ring of the Marsupitidæ. The longitudinal canal, passing through the centre of the stem, is the *axial canal.* In speaking of the form of the stem, allusion is made to the transverse section.

The *crown* consists of *calyx* and *arms;* the former encloses the visceral cavity; the latter constitute the free appendages, passing off from, and connecting with the calyx.

The *calyx* is composed of the *dorsal cup,* and the *ventral disk* or *tegmen,* the arm regions forming the line of demarkation between them. The dorsal cup conforms in a general way to the apical or abactinal system of the Echinoderms, the ventral disk to the oral or actinal system.

The *dorsal cup,* in its simpler form, is constructed of *basals, infrabasals,* when present, and *radials;* to which must be added the *anal* plates, which, however, are not always represented. In the more complex form it includes also some of the lower brachials, which have been incorporated into the walls, either by lateral union among themselves, or by means of interradial and interaxillary plates; the last mentioned plates, in that case, also forming part of the cup. All Crinoids belonging to the simpler form are distinguished as *Crinoidea Inadunata;* those of complex form, *when the calyx is rigid,* as *Crinoidea Camerata,* but when *flexible,* as *Crinoidea Articulata.*

The *base,* or part next to the column, may be composed of one or two rings of plates, which are distinguished as *basals* and *infrabasals.* The basals adjoin the radials and alternate with them, being interradial in position. The infrabasals, when present, are radially disposed below the basals. Crinoids in which the base consists of a single ring of plates are called *monocyclic;* those with two rings, *dicyclic.*

The radials consist of the first plate of each ray, and all plates beyond this in radial succession are *brachials; fixed* brachials so far as they take part in the calyx, *free* brachials or *arm plates* when they do not. In some of the earlier Crinoids one or more of the radials are bisected transversely, in which case the two parts are distinguished as *super-radials* and *infer-radials.*

The *arms* may be simple or branching. When the divisions are of equal size, and rise to the same general height, they are regarded as parts of the arms *proper;* but when smaller and shorter than the main arms, they are called *armlets.* If there are small lateral appendages, given off alternately from opposite sides of the arms, they receive the name *pinnules.* The arms are *uniserial* when their joints extend through to both sides of the arm; *biserial* when they do not, but interlock from opposite sides.

The brachials succeeding the radials (the first axillary included), whether free or fixed, are called *costals,* or *primary* brachials; those of the second order *distichals,* or *secondary* brachials; those of a third order *palmars;* and all succeeding brachials, whether there are additional divisions in the ray or not, receive the name *post-palmars.* When in the description of a species it is necessary to specify any of these plates, they are distinguished as brachials of the fourth, fifth, or sixth order, and so on to the last bifurcation. We also find it convenient occasionally to refer to them as the plates beyond the fourth, fifth, or sixth axillary; or, when free, as plates of the first, second, or third division of the arms. The plates of the different orders, according to their rank, are distinguished as first, second, or third costals, distichals, palmars, etc., and the bifurcating plates as the *axillaries* of their respective orders. All these appellations, however, are not applied to the divisions formed by the armlets and pinnules, although the plates which support them are in fact axillary, and each armlet or pinnule is morphologically the homologue of a whole dichotom.

When two or more arm joints meet transversely by a rigid suture, and only the upper one is pinnule-bearing, those joints form a *syzygy,* whether the apposed faces are radiated, dotted, or smooth; the lower joint bearing no pinnule is called the *hypozygal* joint, the upper one the *epizygal.*

The spaces between the rays and their subdivisions are filled by supplementary plates. Those between the rays proper are designated by the general term *interradials,* whether they belong to the dorsal cup or to the ventral disk. Those of the dorsal cup, which are interposed between the brachials, are distinguished as *interbrachials,* and those of the ventral disk, which lie between the ambulacra, as *interambulacrals.* Plates between the radials at all five sides are only found in dicyclic Crinoids, but in most of the Palæozoic Crinoids there are one or more such plates at the posterior side — the so-called *anal* plates.

The *anal plates* form the base of the anal structures, and consist of the *special* or *first* anal plate, which, when present, invariably rests upon the truncated upper face of the posterior basal, and between two radials. Most of the Camerata also have auxiliary anal plates, which may be present even when the special anal is wanting; they are interposed between the interbrachials, following the median line of the posterior area. Another plate, the so-called "second anal plate" of American authors, which only occurs in the Inadunata and Articulata, is now called the *radianal.* It rests within the re-entering angle of two adjoining basals to the right of the first anal plate, and is the lower half of a bisected radial, which only in some genera assumes anal functions.

Certain groups have interaxillary plates, which occupy the spaces within the axil of the distichals and palmars; the plates between the former are the *interdistichals;* those between the latter the *interpalmars.*

The ventral disk embraces the *disk* ambulacra, the mouth, and the anus. It is formed by the *orals*, the *ambulacral* and *interambulacral* plates. The posterior side of the disk in certain forms of the Inadunata, to which we have given the name *Inadunata Fistulata* is extended upward into a large sac or tube, which is called the *ventral sac* or *ventral tube.* This tube is frequently perforated by pores or slits, which probably promoted respiration. Other forms of that group do not have these pores through the sac, but have a single, rather large, profusely perforated plate upon the disk *proper*, between the sac and the mouth, — the so-called *madreporite.* The disk in most of the Camerata has small *respiratory pores* or slits near the arm bases, piercing the sides of the plates. In recent Crinoids, and probably in the Articulata generally, in which the pores penetrate the body of the plates, the perforated plates have received the name *an-ambulacrals.*

The *anus* is interradial in position; its opening may be either central, subcentral, excentric or marginal; placed at the distal end of a tube, or opening directly through the disk.

The "*anal*" tube must not be confounded with the "*ventral*" tube of the Fistulata, which often does not contain the anus, but when it does, the opening is generally on the anterior side.

The *mouth* occupies the centre of radiation, and is *tegminal* or *subtegminal.* If it is *tegminal,* the opening is surrounded either by the orals and the ends of the ambulacra, or, when the orals are absent, by interambulacral plates, which form a lip around it. If *subtegminal,* it is completely closed, either by the orals or interambulacral plates, which form a roof over it.

The *ambulacra* diverge from the mouth to the tips of the rays, following the ventral furrows of arms and pinnules. When subtegminal, they enter the calyx by means of the *ambulacral* or *arm openings* at the upper edge of the dorsal cup; when tegminal, they follow the surface of the disk. They contain the *food-groove*, the *ambulacral vessels*, the *ovarian tube*, and the *axial canal*. The *food-groove* forms the upper passage. It is followed in descending order by the *subtentacular* canal, the *genital* canal, and the *axial* canal. The axial canal contains the *axial cords*, which communicate with the *chambered organ* at the dorso-central basin of the calyx. The axial canals, in most of the Palæozoic Crinoids permanently, and in the *Antedon* larva temporarily, are mere grooves at the bottom of the ventral furrow, but in the mature recent Crinoid, and in a few Palæocrinoidea, are separated from the furrow by a limestone partition.

The *ambulacral plates* consist of the *ad-ambulacral* or *side-pieces*, and the *covering plates*, or *Saumplättchen;* the former, when present, constitute the outer, the latter the inner rows of the plates. The covering pieces form a roof over the food grooves, and are generally represented by two alternating rows of small, more or less regularly arranged plates, which in all Crinoids are movable upon the arms and pinnules, but upon the disk only in those in which the mouth is exposed. In some of the Camerata the plates are so highly differentiated, that they have been regarded as altogether different structures, and were called *radial dome plates.* We retain this name as a conventional term for the large isolated plates of that group to distinguish them conveniently from the ordinary covering pieces.

The *orals* consist of the five large interradial plates which surround the mouth or cover it, and are either symmetrical or asymmetrical. They are symmetrical when of nearly the same size and form; asymmetrical when the posterior plate is pushed in between the other four. In some species they occupy the entire ventral surface of the calyx; in others, only a comparatively small space in the middle; or they may be completely resorbed in the mature individual.

The *interambulacral* plates occupy the spaces between the ambulacra, their main trunks as well as their branches. We also apply the term to the plates covering the ambulacra, and to those encroaching upon them from the sides, as in many species of the Camerata in which the disk ambulacra are subtegminal or partly so.

The term *perisomic plates* is given to all plates which are originally developed from simple, cribiform films of limestone. They comprise the interradials and interaxillaries, the anals, and all ambulacral and interambulacral plates.

The plates of a Crinoid are united either by suture or by muscular articulation. The former may be a *close* suture, a *loose* suture, or an *anchylosis*. A close suture is nearly or perfectly rigid; the apposed faces are flat, and may be smooth or striated. In a loose suture the faces are more or less concave or excavated, lodging bundles of ligament, so as to give to the plates a considerable amount of mobility. An anchylosis is a modified close suture, in which the lines of union have been obliterated by subsequent limestone deposit. In a muscular articulation, the apposed faces are perforated, and provided with a transverse ridge, or a sort of ball-and-socket joint.

The orientation is based upon the natural position of the Crinoid, *i. e.*, the arms uppermost, viewing the specimen from the anal side. The anal interradius will then be posterior, the radius opposite to it anterior, and right and left will correspond with the right and left of the observer. Next to the anterior ray are the two antero-lateral rays,* and adjoining the anal interradius the right and left posterior rays. Corresponding appellations are applied to the interradial spaces, which consist of the two anterior, the two antero-lateral, and the posterior or anal, interradii.

In illustrating the plates of the calyx, the dorsal view is figured with the anal interradius *up*, and the ventral view with the anal side *down*. Right and left remain the same in both cases.

The terms *proximal* and *distal* are reckoned from the chambered organ, so that the infrabasals and the top-stem-joint are the proximal elements of crown and stem respectively. In the crown, the outer surface of a plate represents the dorsal side, its lower edge the proximal face, its upper edge the distal face, and the faces at the sides are the lateral faces. In the stem, however, the *upper* face is the proximal, and the lower one the distal.

* These rays are called by Mr. Bather the right and left "anterior" rays. The term is objectionable because we have already the anterior ray proper.

# MORPHOLOGICAL PART.

## PRIMARY AND SUPPLEMENTARY PLATES.

The plates of the Crinoids fall naturally into two categories, viz., *primary* plates, and *secondary* or *supplementary* plates. The primary plates are the first parts developed in the larva. They are represented in every group of the class, and undergo comparatively few modifications in geological time. The supplementary pieces appear in the growing Crinoid, but are unrepresented in some of the groups. They are interposed between the primary plates, and help to increase the capacity of the visceral cavity. They are very important in point of classification, offering by their presence or absence, their position and distribution in the calyx, their arrangement and multiplication, excellent criteria for natural divisions.

The primary plates may be subdivided into two classes: plates of the abactinal system, and plates of the actinal system. The former are developed on the right larval antimer, and include all plates connected with the chambered organ and the axial cords. The latter are developed on the left antimer, and communicate with the mouth and the annular vessels surrounding it. The abactinal plates are represented by the stem joints, the basals, infrabasals, radials, and the plates forming the dorsal parts of arms and pinnules; the actinal plates by the orals and ambulacral plates to the ends of the brachial appendages. The remaining plates will be treated by us as supplementary pieces.

## I. THE PLATES OF THE ABACTINAL SYSTEM.

### A. *The Stem and its Appendages.*

The length of the stem in some Mesozoic Crinoids must have been enormous. Quenstedt traced that of a Jurassic *Pentacrinus* to 70 feet without reaching either end. This is in striking contrast to its length in Palæozoic forms. Among them the two longest stems observed by us have a length of about three feet, — one, not quite complete, being that of a large *Megistocrinus Evansi*, the other, which is perfect, of a *Strotocrinus regalis*, two of the largest known species. That seems to have been about the maximum length, and it may be safely asserted that the stem in the majority of the older Crinoids was not much over a foot long. Some stems are proportionally wider at the top, and taper all the way to the root; others are larger at the distal end than at the proximal; while still others are widest in the middle.

The root is even more variable. Its form was evidently accommodated to the conditions of the place of its attachment. When attached to a solid substance, it was flattened at the distal face, the radicular cirri spreading out horizontally; but when growing on an oozy bottom, it gave off long vertical and lateral branches, entering the mud.

The stem is either circular, elliptic, pentangular, stellate, semilunate, or quadrangular, changing from angular to round on approaching the root. It is composed of joints, which vary often considerably in size. Certain of these joints, which have been denominated "nodal" joints, are separated from each other by intervals of different lengths, which are filled by internodal growth. The nodal joints are not only longer than the internodal ones, but also wider, and, as a rule, increase in length downward. Their diameter is greatest in the upper part of the stem, where in some species of the Camerata it is often twice, and exceptionally three times, that of the internodal joints. The projecting margins are sometimes knife-like, the edges occasionally crenulated, spinous, or nodose. The greater amount of length which characterizes these joints, however, does not extend to their full thickness, but is more or less restricted to the projecting margins, the middle part at both ends being depressed, so as to enclose wholly or in part the adjacent internodals.

In the growing Crinoid, the stem constantly increased in length by the production of new joints, introduced either directly beneath the calyx, or at some distance from it. The joints which are formed at the proximal end of the stem gradually developed into nodal joints, and all those intervening comprise the internodal joints. The nodal joints of the Inadunata and Camerata, and also of many of the later and recent Crinoids, were introduced directly beneath the basals and infrabasals respectively, so that the uppermost joint was always the youngest joint of the stem. But in the young Comatula, in which the top joint subsequently develops into a centrodorsal, in the recent Mesozoic *Millericrinus*, and probably in the recent *Rhizo-*

*crinus* and *Calamocrinus*, and in all Ichthyocrinidæ, so far as observed, the new nodal joints were formed beneath the top joint, and the latter remained permanently attached to the calyx. In *Apiocrinus*, in which for some distance the upper end of the stem is greatly inflated, and the proximal joints extremely long, it is possible that the nodal joints were introduced below the inflated part, for there appear to be no immature segments between the upper joints.

The internodal joints, as stated, are placed between the nodal ones; and the spaces which they occupy, and which continually increased in length and width in the growing Crinoid, are the internodes.

The increase in the length of the internodes took place gradually in a downward direction — as may be seen by comparing the stem of a young specimen with that of an older one — and *pari passu* with the formation of new joints just below the calyx. Hence in the upper part of the stem there is a variable number of premature internodes. Those nearest the calyx are the shortest, and consist of the smallest number of joints; while the internodes in the lower part of the stem all contain the same number of pieces, and all joints have approximately the same proportions. The joints of the upper part vary in the same internode from a growing leaflet, invisible in a side view, to an almost fully developed joint; and the upper internodes frequently consist of single pieces. But they are followed more or less rapidly by internodes of two, three, or as many more ossicles as it required to complete the maximum number of the species, the younger joints being inserted next to the older ones, which are distinguished by their greater prominence. In the upper part of the stem, the joints of subsequent growth are readily recognized, in some species more so than in others; but toward the terminal end, where all ossicles attain almost an equal size, it is often difficult. The stem matured from the root up, and remained at the upper end permanently in a state of immaturity.

The maximum number of internodal joints varies considerably among the species. There may be only one or two to the internode throughout the stem, or many more. The largest number observed in Palæozoic Crinoids is about fourteen; but among recent Pentacrinidæ as many as forty-five have been counted, and as many as seventy in Mesozoic species.

The internodes of some species begin at quite a distance from the calyx, while others have no internodal joints at all. The former is manifestly the case in certain genera of the Ichthyocrinidæ, in which the upper part of the stem is enlarged somewhat as in *Apiocrinus*, except that the joints of the enlarged part in the Ichthyocrinidæ are very short, and increase but very slightly in length downward. These plates, which have no internodals interposed, extend to the full length of the inflated part, and their number varies in different species from about twenty to fifty, but is constant, or nearly so, in the same species. They are followed distally by a large prominent joint, from which the internodes begin. The latter are formed in the usual way, larger and smaller joints following each other at intervals, and the nodal joints are rather prominent.

The stem of a *Platycrinus* has generally no internodes, and all young joints were introduced next to the basals. The joints are elliptic, and the apposed faces of the joints throughout this genus are provided with articular ridges, which follow their long diameters. A similar structure occurs in the recent *Rhizocrinus* and *Bathycrinus*, and both of them are apparently destitute of internodals. The Silurian *Marsupiocrinus*, however, with a circular stem, which is otherwise most closely allied to *Platycrinus*, always has well defined internodes; and this forms perhaps the best distinction between the two genera.

The absence of internodals is not confined to specimens with elliptic stems, or to those with articular ridges. They are wanting also in *Mespilocrinus* with a round stem, and in which the joints rapidly attain a length of from three to four times their diameter (Plate II., Fig. 3). In *Rhodocrinus* there is, so far as observed, but a single ossicle to each internode, and throughout the stem a larger plate alternates with a smaller one.

In a few Palæozoic Crinoids, the whole stem is divided longitudinally, its joints being either quinque- or tri-partite. The former is the case in *Ohiocrinus*, *Ectenocrinus*, *Barycrinus*, *Anomalocrinus*, and probably others; while a tri-partite stem has been observed only in *Heterocrinus*. The stem segments alternate with the proximal plates of the calyx; *i. e.*, they are interradial in dicyclic, and radial in monocylic Crinoids.

Most Crinoids are provided with cirri, which are given off from the nodal joints at intervals, either throughout the whole length of the stem, or only at its distal end. The former is more generally the case among the later Crinoids, while in the majority of Palæozoic forms the cirri are restricted to the lower part. In Neocrinoids they are more regularly distributed, and occur in whorls; in Palæocrinoids they are generally arranged singly, and at irregular intervals. The Pentacrinidæ have five cirri to each nodal joint, which are invariably radial in position; or three cirri from one node, and two from the adjoining ones, so arranged that the cirri of two joints correspond in position to the five of the one joint. The size of the cirri varies among species, some being much stouter than others and also longer; but as a rule, they increase somewhat in length downward, and taper to the end. They move rapidly, according to A. Agassiz,* quicker than the arms, and are used "as hooks to catch hold of neighboring objects, and on account of their sharp extremities are well adapted to retain their hold."

The functions of the cirri in Palæozoic Crinoids were probably more limited than in recent ones, for in most of them any rapid movement would be incompatible with the structure. This is especially the case with those of the Camerata, and it may be a question whether these appendages should not receive a different appellation.

The cirri of the Camerata, except perhaps those of certain species of *Dichocrinus*, are mere branches of the stem, and were obviously capable of very little motion. They occur only in the lower part of the stem, and in many cases were probably restricted to the root. They rest within sockets, formed at the sides of the stem by a truncation or excavation of one or more stem joints. In *Platycrinus*, in which we have observed the complete stem more frequently than in any other genus, they generally occupy from one-fourth to one-third of its length, and, being given off invariably from the longer diameter of the stem, they follow its twist. In some of the species, each successive joint is cirrus-bearing, either at both sides of the stem or one side alternately. In others, the cirri are given off at irregular intervals, and vary considerably in length and width. Throughout this genus they are attached to one stem-joint only, which, when the base of the cirrus is larger than the usual length of the joint, is lengthened on that side to accommodate it. The radicular cirri are larger than the others, and are generally provided with numerous small branchlets. The distal end of the stem also terminates in a sharp point.

In stems with internodal joints, the cirri do not rest alone against the nodals, but the adjoining internodals share in the formation of the cirrus sockets. In some species the sockets involve only the adjacent joint above and below; in others, two or three of them; but the cirrus canal invariably communicates with the axial canal of the stem through the nodal joint. The

* Letter No. 3, on the Dredging Operations of the U. S. Coast Survey steamer Blake, from December, 1878, to March 10, 1879. Bull. Mus. Comp. Zoöl., Vol. V., p. 296.

cirri, although they may be arranged singly at wide intervals, are located radially in dicyclic Crinoids, and interradially in monocyclic ones. This is readily perceived on pentangular stems, in which the cirri rest within the retreating angles of the joints, so as to alternate with the salient angles, and hence are in line with the salient angles of the axial canal.

The length of the cirri among Camerate Crinoids was very variable, and they were in some species quite formidable. We have in our collection a fragment from the lower part of the stem, apparently of *Batocrinus grandis* (Plate I., Fig. 2), measuring 11 cm. in length, and tapering from a diameter of 10 mm. at one end to 7 mm. at the other. It gives off numerous cirri, of which those of the thicker or upper end are but little thinner than those of the lower. Three of the lower cirri are preserved to a length of 16, 15½, and 15 cm. respectively, and may have been much longer, as they taper but little, still having at their ends a thickness of 2½ to 3 mm. Five other cirri are broken at a length of from 11 to 37 mm., and eight consist of only two to five joints; while the sockets of three others are empty. The sockets are deeply excavated, and extend to nine joints, the surface being radiated. The distal faces of the joints are slightly concave, the proximal joints shorter than the distal, and the central perforation is round and of moderate size. Two of the cirri in this specimen have a remarkable cyst of 14 to 18 mm. in length by 9 mm. greatest width, one forming the distal end of the longest cirrus, the other commencing about 8 mm. from the stem. The two thickest joints in the inflated part of the one are nearly 4 mm. long, while the length of the joints above and below the inflation does not exceed 1½ mm. Similar cysts are frequently found along the stem, but have not before been observed to occur on the cirri. They resemble the Myzostoma cysts, which occur along the arms of recent Comatulæ, and like them were evidently caused by parasites.

In another stem fragment from the Upper Helderberg of Louisville, Ky., every joint is cirrus-bearing, and most of them have five large cirri — some four or three — which almost touch those above and below. The cirri are preserved to a length of 35 to 40 mm., and were probably much longer (Plate I., Fig. 3).

The cirri of the Actinocrinidæ generally extend to one third the height of the stem. They vary greatly in size, and are arranged at rather wide intervals. The same structure probably prevailed in the Ichthyocrinidæ, at least in *Onychocrinus* and *Taxocrinus;* while in the Calyptocrinidæ cirri occur only at the distal end, where they form a large root with hundreds of small, very delicate branchlets.

In *Dichocrinus* the distribution and length of the cirri are extremely variable. In some species they only occur at the lower part of the stem, where they are short and arranged far apart. In others they continue up to near the calyx, and are quite long. The former is the case in *D. inornatus*, in which they are singly arranged, and rather slender. In *D. parvulus* and *D. delicatus*, however, they follow the whole length of the stem, and are arranged in sets of two or more, which are so long that the tips of the upper ones reach up to the arms. But the most remarkable cirri occur in the Carboniferous *Camptocrinus myelodactylus* (Plate LXXV. Figs. 1 and 2) and *C. cirrifer* (Plate LXXVI. Figs. 13 *a*, *b*, *c*), in which they begin at a short distance from the calyx. The stem, as usually found in these species, is coiled around the crown; the joints are circular at the top, but gradually become crescent-shaped, the concave side of the crescent directed to the inner side of the coil, and both its horns giving off extremely long cirri from alternate sides. Very similar cirri occur in the Fistulate genus *Herpetocrinus*, from the Silurian of Europe.

*Glyptocrinus* apparently had no cirri at all, not even at the distal end, and the stem was probably attached like that of the Comatulæ in their larval state by means of a dorso-central, i. e., the enlarged terminal plate. *Rhodocrinus nanus* and *R. Kirbyi* have a few scattered cirri at the lower end, singly arranged.

The cirri of the Inadunata, so far as observed, are not only more slender, but were apparently more flexible than those of the Camerata, and they pass up more frequently to the top of the stem. The latter is often the case among the Poteriocrinidæ, especially in *Scaphiocrinus* and *Graphiocrinus*, in which the nodal joints have variously from one to five rather delicate cirri. That these appendages were highly flexible is shown by the fact that they bend in all directions, — some being straight, others curling, some directed upward, others downward, — a feature very different from that shown in the Platycrinidæ, Actinocrinidæ, and Batocrinidæ.

*Belemnocrinus florifer* has very long and slender interradially disposed cirri, which extend to the full length of the stem. It has three or four from each nodal joint, the upper ones directed upwards, and extending to half the height of the arms. *B. typus*, on the contrary, has no cirri to a length of 13½ cm., and the stem is circular instead of stellate.

In the Cyathocrinidæ the structure at the lower part of the stem is only known in *Barycrinus*. In *Cyathocrinus* we have examined the stem to a length of 10 cm., and in *Parisocrinus* to about 18 cm., without finding any traces of lateral cirri. Neither have these been observed, so far as we know, among the Anomalocrinidæ or Hybocrinidæ; but in *Homocrinus scoparius* they occur at the lower half of the stem.

The stem of *Barycrinus* is quinque-partite, and enlarges gradually to the root, where its diameter in extreme cases reaches from 30 to 40 mm. The root consists of five main rami, which branch into smaller ones, so located that the longitudinal sutures of the stem bisect the rootlets, and the large central canal, which is sharply pentangular in the stem, becomes elliptic or linear within the branches; the latter is also the case in *Ancyrocrinus*, of which we shall speak presently.

The axial canal is central, and extends to the full length of the stem, giving off branches to the cirri. The main canal is circular, angular, or pentalobate; that of the branches sometimes elliptic, the long diameter vertical. If pentangular, the angles are directed radially in dicyclic Crinoids, and interradially in monocyclic, thus alternating with the projecting angles of the stem joints. To this rule, however, there are two exceptions, and, so far as we know, only two. In *Pentacrinus*, and the monocyclic *Glyptocrinus Fornshelli* S. A. Miller, the axial canal has the same orientation as the outer angles of the stem. This is very remarkable, and we shall consider it further in discussing the basals and infrabasals. The canal in some species is quite minute, in others very wide; while in still others the central canal is surrounded by three, four, or five peripheral canals, as in the case of *Cupressocrinus*, in which pentamerous symmetry in the stem is the exception.

In recent Crinoids the innermost part of the central canal is the internal vascular axis, and consists of five peripheral vessels arranged around a central one. The former are downward extensions from the chambers of the quinquelocular organ at the base of the calyx, which are connected with the axial vessel of the chambered organ. Whether such vessels also existed in the stem of Palæozoic Crinoids, of course cannot be ascertained from the fossil; but that a quinquelocular organ, with upward extensions to the arms, was present in some of them, is indicated by the structure of *Eupachycrinus*, *Catillocrinus*, and *Agassizocrinus*, where the inner floor of the basals and radials is apparently perforated. Carpenter* thinks it probable

* Journal of Anatomy and Physiology, Vol. XII., p. 44.

that the peripheral canals of *Cupressocrinus*, which consist variously of three, four, or five separate passages, correspond to the peripheral vessels of *Pentacrinus*, *Rhizocrinus*, and other recent Crinoids. He directed attention to the fact that there is among different individuals of the same species considerable variation in the isolation of these vessels. In some species, in which the canals appear to be continuous, there is but one large tri- or tetra-partite perforation at the base of the calyx and throughout the stem, which he thinks enclosed the four, five, or six separate vessels of other specimens. This may be so, although we cannot quite understand how the three or four peripheral canals, where they exist, can be extensions of a quinquelocular organ.

The variation in the size of the axial canal among Palæozoic Crinoids is most remarkable. In *Platycrinus* the canal is sometimes no larger than the point of a needle; while in *Barycrinus*, *Crotalocrinus*, *Enallocrinus*, *Megistocrinus*, *Periechocrinus*, etc., it is often from one half to even three fourths the width of the joints, and is either round or pentangular. In some of them the walls within appear as if built up of thin laminæ with spaces between, sometimes pectinated and variously sculptured, producing a great multiplication of exposed surfaces. In *Barycrinus*, with a quinque-partite stem, and a sharply stellate canal, of which the projecting angles are directed radially toward the suture lines, the trigonal inward extensions of the canal are pierced by one or more rather large pores, which pass through the body of the plates, so as to enter the outer faces of the stem, as shown on Plate I. Figs. 6 and 8 *a*, *b*. Five other series of pores follow the longitudinal suture lines, and these also communicate with the central canal.

In the Crotalocrinidæ and Periechocrinites, in which the central cavity is proportionally still larger than in *Barycrinus*, the inner structure appears to have been less complex; but its extreme size in both groups, compared with that of other Crinoids, and especially with recent ones, seems to imply that it was not a mere axial canal, but performed additional functions.

We have in our collection the root of a large *Barycrinus* (Plate I. Fig. 7), which must have been attached to a smooth, solid substance, for the lower surface of the root is perfectly flat. In this root only two of the five primary branches were developed, and these are but partly preserved, but enough is seen to show that they had been placed on a level with the truncated lower face of the main trunk. The development of the other three cirri seems to have been checked by contact with the bottom, but their outlines are faintly indicated along the edges of the specimen. The middle part of the truncated lower face is perfectly flat, and there are no traces shown of an axial canal. But in an outward direction we find grouped around a closed centre numerous small canals connecting with the interior. These canals form upon the surface well defined ramifying grooves, which pass out to the periphery, and seem to communicate with the surrounding water. In another detached root, likewise with a flat bottom, the ramifications at the distal end were not exposed in the specimen, but were opened out by grinding. The specimen has two root trunks of equal size, which are united at the bottom by an irregularly formed limestone deposit, and around the projecting truncated lower end there are a number of small openings, which connect with the canals from the two rootlets. Whether the cirri of all Palæozoic Crinoids open out at their ends, will perhaps never be satisfactorily ascertained. We may state, however, that the finest hair-like branches which have come under our observation are perforated at their extremities.

When in the Revision we directed attention to the variations in the size and complexity of the axial canal (Part I., p. 15), we suggested that the column was probably in some cases, and perhaps in all Palæozoic Crinoids, subservient to respiration. To this Dr. P. H. Carpenter* replied that he did not think it unlikely that the pores near the base of the column may have served to admit water into the stem, and thence into the cœlom; but he doubted if the canals opened at the ends of the rootlets, concealed as they were below the surface of the ooze, as the water introduced to the stem by these passages could not have been very useful for respiratory purposes. Neumayr† regarded the stem of the Crinoids a greatly modified organ, whose original form could only be explained by the structure of certain Cystids; and he thought it was primitively, as it is in that group, a sac-like extension of the calyx, and was plated in a similar manner. In corroboration of his views, he alludes to our observation that in Crinoids with pentangular stems the faces and angles of the stem occupy a definite position to the proximal ring of the plates in the calyx.

Similar views were expressed by A. Agassiz.‡ He says: "That the pentagonal stems hold a definite relation to the calyx has been clearly shown

* Quart. Journ. of Geol. Soc., 1880, pp. 555–557.
† Stämme des Thierreiches, p. 430.
‡ Calamocrinus: Mem. Mus. Comp. Zoöl., Vol. XVII., p. 63.

by Wachsmuth and Springer, and goes far to prove that the stem must originally have had a far more intimate connection with the calyx than its representatives of to-day have; and the fact that in a number of Palæozoic Crinoids the axial canal is very wide, compared with that of recent types, seems to indicate an additional function to that of the axial canal, which, as Neumayr suggests, we cannot explain from recent representatives."

The apposed faces of the stem joints, with a few exceptions, are marked by a series of more or less well defined angular ridges and alternating furrows, which radiate from the opening of the central canal toward the dorsal margin of the joints, but occasionally are restricted to their marginal portions. The principal ridges alternate with smaller ones, which do not extend as far inward as the others, and all ridges of one joint meet corresponding furrows of the apposed joint, which gives to the suture its serrated outline. The faces of the joints are flat, or slightly curved, the nodal ones having sometimes a slight crest around the canal, which fits into a corresponding depression of the apposed internodal. This indicates that the motion of the stem was quite limited, and, as Carpenter remarks, "only of a passive character, due to the current of the water, etc., and independent of the will of the animal." On coming in contact with other animals it was capable of bending sideways, and of returning to its natural position when the obstruction was removed.

In *Platycrinus* and *Bourgueticrinus*, in which the faces of the stem joints are elliptic, their surfaces are provided with a well defined transverse ridge following the long diameter of the joints, with fossæ at both sides, and surrounded by a marginal reticulation. The ridges follow the twist of the stem downward, admitting motion in all directions. In these families there seems to have been a sort of rudimentary articulation between the successive joints, while in the other families there was only a loose sutural union.

As to the habits of Crinoids, very little is yet known, even of the recent ones. We know that in their pedunculate state the Comatulæ were fixed by means of a large plate, the so-called dorso-central; and this led to the belief that all Stalked Crinoids were permanently attached in a somewhat similar manner. But this has never been satisfactorily proved, and, as we know now, is not always the case with the recent Pentacrinidæ. The distal end in most Palæocrinoidea tapers rapidly and uniformly to a point, and the terminal branches are given off from several joints, and not from a single one, except in a very few cases. In the Hudson River group of Cincinnati we occasionally find crinoidal disks, attached to pieces of coral, which closely resemble the dorso-central of *Antedon.* These disks have a pit or depression at the middle of the upper face, sometimes enclosing a small stem joint. They are irregularly round, and some of them have small processes passing outward from the sides, which seem to represent primitive cirri (Plate I. Figs. 9, 10). It is now worthy of note, that we find in the same beds some remarkable crinoidal stems, with their lower ends wound around some stem fragment or other object, almost as neatly as thread upon a spool, the column gradually tapering as it coils, and becoming very small at the end.* It has always seemed to us that these stems and the terminal plates belonged together, and were separated during the life of the Crinoid. Detached roots are found in considerable numbers at Burlington and Waldron, and in almost every case the root parted from the stem a little above the radicular cirri; but it is curious that hardly ever are parts of the crown found associated with them. From these facts we may infer that the stem, at least in some cases, became detached from the root, so that the Crinoid could change its place of attachment. A detachment of this kind actually took place in a large number, if not in all, recent Pentacrinidæ, as shown by Sir Wyville Thomson,† P. H. Carpenter, and others. The former describes this structure in *Pentacrinus Wyville-Thomsoni* as follows: "All the stems of mature examples of this species end inferiorly in a nodal joint surrounded by its whorls of cirri, which curve downwards into a kind of grappling root. The lower surface of the terminal joint is in all smoothed and rounded, evidently by absorption, showing that the animal had for long been free. I have no doubt whatever that this character is constant in the present species, and that the animal lives loosely rooted in the soft mud, and can change its place at pleasure by swimming with its pinnated arms; that it is, in fact, intermediate in this respect between the free genus *Antedon* and the permanently fixed Crinoids." Carpenter found a number of other species of *Pentacrinus*, and some of *Metacrinus*, in the same condition. Roots apparently of *Pentacrinus*, and belonging to mature or almost mature specimens, are occasionally found on telegraph cables, but so far as we know, minus the crown and main part of the stem; and it is quite probable that all Pentacrinidæ were able to detach themselves and float about.

* S. A. Miller: Journ. Cincin. Soc. Nat. Hist., Vol III. Plate 7, Fig. 3*b*.
† The Depths of the Sea, pp. 442–444.

Carpenter * further states that in *Pentacrinus Wyville-thomsoni* the nodal joint from which the separation takes place "sometimes loses its ordinary characters altogether, becoming much enlarged and rounded below so as to be almost hemispherical in appearance." And in a foot-note he says: "The unusual enlargement of the nodal joint suggests the idea that the structures which have been described by Hall under the name *Ancyrocrinus* † may be the detached stems of a Palæocrinoid in the semi-free condition," — in which we fully agree with him. *Ancyrocrinus* has the form of an anchor, with four hook-like processes around a central ascending stem, which at its distal end is provided with a small, rounded tubercle, closing the opening of the central canal exactly as in some cases of *Pentacrinus*. That this stem is morphologically in the same condition as that of *Pentacrinus*, nobody will deny after examining the specimens. The four lateral extensions were doubtless radicular cirri, whose joints were obliterated by calcareous overgrowth, as in the lower part of its tetramerous stem.

Something similar to this may have taken place in other Palæozoic Crinoids; and it is quite probable that the terminal end, as it appears in the specimens, is in many cases not homologous with the part by which the young Crinoid had been formerly attached, but is a product of later growth. We suspect this to be the case in the Actinocrinidæ, Platycrinidæ, and other forms in which the terminal part tapers rapidly to a point, and cirri are given off from the sides. It would not be a great departure from the structure of the Comatulæ, if we bear in mind that their centro-dorsal is a modified stem joint, bearing cirri upon its outer surface. The only essential difference would be that in the Palæocrinoid the stem separated at its *lower* end, and in the Comatulæ at the *upper*.

That the young Palæocrinoid in its early life was attached by a dorso-central, we may fairly infer from what we know of the development of the Comatulæ, and from palæontological evidence. The indications, however, leave it somewhat doubtful if the fixation was permanent. We believe that in the majority of cases among the older Crinoids the stem was afterwards separated from the root, and that the animal subsequently led a free life. In only two instances do we know that Palæozoic Crinoids were attached by what appears to have been originally a dorso-central plate: in

* Challenger Rep. on the Stalked Crinoids, p. 19, and foot-note.
† Fifteenth Ann. Rep., N. Y. State Cab. Nat. Hist., 1862, pp. 89, 90.

"*Cheirocrinus*" *clarus*,* and in *Eucalyptocrinus crassus*,† both described by Hall. In the former the plate is fixed to a stem fragment, and closely resembles the plate figured by us on Plate I. Figs. 9, 10, having like that small budding cirri. The *Eucalyptocrinus* is a young specimen, which may have perished before reaching the free stage. Detached roots of this species have been found in large numbers, even larger ones than that figured by Hall. In some localities they are so abundant that they lie in contact in the rock; but they are very rarely associated with pieces of the stem proper, or with parts of the crown. These roots seem to have been derived from a central disk (dorso-central), from which the numerous branches were given off in a similar manner as the immature cirri from the terminal plate of "*Cheirocrinus*" *clarus*.

Among recent Crinoids, such terminal plates have been found in connection with fragmentary stems in *Calamocrinus Diomedæ* Agassiz,‡ and in *Pentacrinus naresianus* Carpenter,§ in which the stem increases in width downward; but it is uncertain in both cases whether the stem is fractured or had been cast off by the animal. Different is the structure in a specimen of *Rhizocrinus Rawsoni*, figured by Carpenter,‖ in which it seems as if the dorso-central is unrepresented. There are given off from the sides of the last stem joint a few irregular cirri, directed downward, and the distal end of the joint is closed, as in the case of semi-free Pentacrinoids. The last joint differs in no other way from the joints above, and has the same form and length as the preceding one.

Among Palæozoic Crinoids we have seen the complete stem in upwards of thirty specimens of various genera, but none of them had a dorso-central, or a surface for attachment; the stems invariably terminate in a point. The terminal portion, however, forms no part of the primitive stem, but is of later growth, and probably served the same purpose as the lateral cirri.

Now if it is true that the young Crinoid was attached by a dorso-central, as we may suggest from the ontogeny and phylogeny of the group, then all these specimens are morphologically in about the same condition as the semi-free Pentacrinidæ, and not essentially different from that of the free floating Comatulæ. This interpretation seems far more reasonable than the supposition that these Crinoids were permanently attached.

* New York State Cab. Nat. Hist.; Fifteenth Rep., Plate I. Figs. 17 and 18.
† New York State Museum Nat. Hist.; Twenty-eighth Rep., Plate 17, Fig. 5.
‡ On Calamocrinus; Mem. Mus. Comp. Zoöl., Vol. XVII. Plate 28, Figs. 2, 3, 4.
§ Chall. Rep. on Stalk. Crin.; Plate XXX. *a*, Fig. 4.
‖ Ibid. Plate LIII. Fig. 7.

A permanent fixation of the Crinoids would perhaps restrict the geographical range of the species, whereas we know that some of them have a very wide range. A majority of the species from the Lower Burlington group at Burlington are found almost unaltered in the southwestern part of New Mexico, and some in Arizona, and many species of the Keokuk group have been traced from southern Iowa as far down as Alabama. And we find in Scotland and eastern Russia, with but slight modifications, the same forms which flourished in the Mississippi Valley during the epoch of the Kaskaskia group.

B. *Basals and Infrabasals.*

The base of a Crinoid consists either of one or two rings of plates, to which the terms "basals" and "infrabasals" are applied. In dicyclic forms, the infrabasals constitute the proximal ring of the calyx; the basals the next circlet above. The former are radially disposed, the latter interradially. The plates of either ring are in contact laterally, except the basals in a few species of *Zeacrinus* and *Calpiocrinus*, where the truncated lower angles of the radials, and occasionally the radianal, reach down to the infrabasals. The basals are followed directly by the radials, except in the Acrocrinidæ, in which they are separated from the latter by a belt of auxiliary pieces, which occupy a large part of the dorsal cup.

The term "basals" was applied by the earlier writers invariably to the proximal ring of the calyx, and when there were two rings, the plates of the upper one were called "subradials" by some authors, while others called them "parabasalia." To Dr. P. H. Carpenter * belongs the credit of having been the first to point out that in dicyclic Crinoids the so-called "subradials" — and not the proximal ring — are the homologues of the basals in the monocyclic base, and that the lower ring in the dicyclic forms is an additional element in the calyx. He demonstrated that from a morphological point of view the same set of plates cannot be interradial in one genus, and radial in another, and he considered the basals, which alternate with the radials, to be the representatives of the genitals in the Urchins. The force of his argument has been generally acknowledged, and the American authors writing since 1879 have adopted Carpenter's method, with the exception of S. A. Miller, who still clings tenaciously to the old terms. Carpenter called the plates of the proximal ring "under-basals," for which the term "infrabasals"

* "Oral and Apical Systems of Echinoderms." Quarterly Journ. of Microscop. Sci., Vol. VIII., pp. 351–383.

has been substituted, at the suggestion of Prof. Zittel. But Zittel,* and the German Palæontologists generally, while admitting the homology, and the name "infrabasalia," adopted the term "parabasalia" for the upper ring of plates in the dicyclic base, claiming that the word "basals," if applied to the dicyclic base as well, might lead to confusion.

The practice of giving different names to sets of plates which are admitted to be homologous was justly criticised by Carpenter,† and serious difficulties arise as to which term should be applied in certain groups, where infrabasals exist in some species and are wanting in others. Such a case is presented by the Apiocrinidæ, among which de Loriol discovered rudimentary infrabasals in two species of *Millericrinus*.‡ This family was previously supposed to be monocyclic, and the base is described by Zittel as consisting of five *basals*, whereas in the two species above mentioned, the five corresponding plates would be *parabasals*. There is a similar case among the Pentacrinidæ, in which infrabasals are represented in one genus, — *Extracrinus*. In the Comatulæ, in which, according to Bury,§ small infrabasals occur in the ciliated larva, but disappear in the Pentacrinoid stages, the very same plates would be "parabasals" in the earlier stage, and basals in the later. Carpenter is clearly right when he says that this terminology, instead of making it easier to students, as claimed by the German Palæontologists, would be the source of endless confusion.

A different interpretation of the basal plates was given by Dr. J. Walther.‖ He accepts Zittel's terms for descriptive purposes, but homologizes the infrabasals with the basals of the Monocyclica, the "parabasalia" with the monocyclic radials; and he takes the radials of the Dicyclica to represent an entirely new element in crinoid morphology. This recalls the idea of Lyon,** who took the basals of the Blastoids for "primary radials," and the forked plates for "secondary radials." As Walther's views are altogether out of keeping with the facts of Palæontology, and also, as we now know, with those of the embryology of recent Crinoids, any further discussion of the subject is unnecessary.

The Comatulæ have basals only in their earlier stages; during the later

* Handbuch d. Palaeontologie, Vol. I., p. 327.

† Ann. and Mag. of Nat. Hist., July 1890, pp. 5-11.

‡ Paléontologie Française, Tome XI., Part I., pp. 553, 566.

§ "The Early Stages in the Development of Antedon rosacea." Report of the Fifty-seventh Meeting of the British Association at Manchester, 1887, p. 735.

‖ Untersuchungen über den Bau der Crinoideen, Palæontographica, 1886, Bd. XXXII., p. 189.

** Geol. Rep. Kentucky, Vol. III. p. 469.

period of Pentacrinoid life they are transformed into the "rosette," which closes the upper opening of the centro-dorsal cavity lodging the chambered organ. The Eugeniacrinidæ have no basals in the adult, and Carpenter supposed that they were anchylosed with the radials, while Zittel and Jaekel think they were enveloped by exuberant growth of the radials.

In all dicyclic Crinoids the basals, without exception, consist of five plates, and the infrabasals either of five, three, or a single piece. The basals of monocyclic Crinoids vary in number from one plate to five.

The proximal ring, whether consisting of one, two, three, or four pieces, whether basal or infrabasal, is divisible into five elementary plates; and the smaller number, where it exists, is produced, as we shall presently show, by anchylosis of two or more of the primary segments, accompanied by a more or less complete obliteration of the suture lines.

The earliest dicyclic Crinoids had five infrabasals, and the first monocyclic ones five basals. Before the close of the Lower Silurian, there appeared two monocyclic genera with four basals, both having a special anal plate interposed between the radials. The quadripartite base reached its culmination in the Upper Silurian, and disappeared before the close of the Devonian.

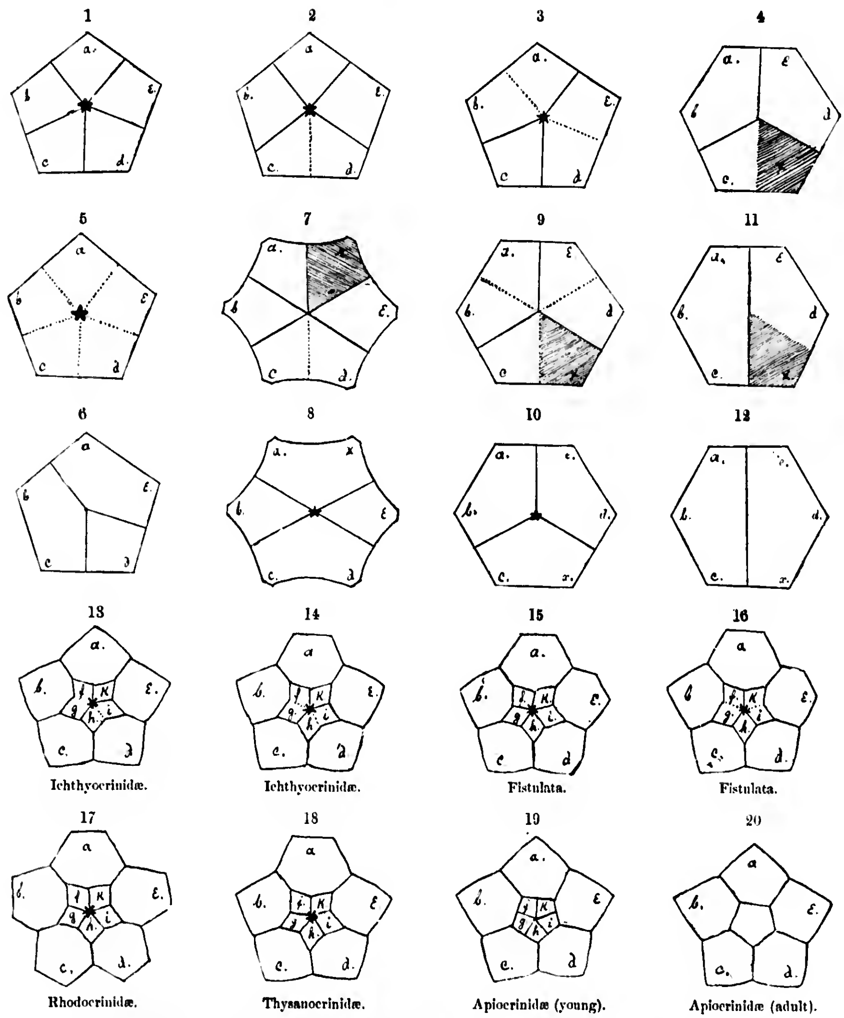
The earliest genera with a tripartite base occur in the Upper Silurian; some of them have an anal plate, and others not. When that plate is represented, the basals are of equal size; when absent, two of the basals are equal, and the third about half smaller. The two forms continued to exist side by side to the end of the St. Louis group of the Carboniferous, when both became extinct.

The bipartite base is restricted to the Carboniferous. It occurs from the Kinderhook group up to the Coal Measures, but is found only among genera with a large anal plate.

It is evident from these observations that the number of basals was gradually reduced in Palæozoic times, and that in the Camerata the anal plate was introduced after the quadripartite base had made its appearance. It will now be shown that this diminution of number was the result of fusion of two or more of the five original plates, and that by the introduction of the anal plate the base underwent further modifications. The manner in which the modifications in the number of basals and infrabasals were effected, may be best understood by reference to the diagrams on Table A.

Looking at these diagrams, the transmutation in the Camerata from five

## TABLE A.




DIAGRAMS ILLUSTRATING THE EVOLUTION OF THE BASALS AND INFRABASALS.

All figures represent the anal side at the top; $a$ = posterior basal; $b$ and $e$ = postero-lateral basals; $c$ and $d$ = anterior basals; $f$, $g$, $h$, $i$, $k$ = infrabasals.

basals to a less number, is readily understood among genera in which the anal plate is wanting. When the base is quadripartite, it is invariably the two anterior plates of the elementary five which are consolidated (Fig. 2). In the tripartite base there is a fusion of the posterior with the left postero-lateral basal, and another between the right posterior and adjoining antero-lateral-plate (Fig. 3). The figure shows that a bisection of the two larger plates will reproduce the original five pieces, interradially disposed.

The case is not so simple in genera with an anal plate, where the form of the basal disk is changed from pentagonal to hexagonal (Fig. 4), as a bisection of the larger plates would produce six plates instead of five. This difficulty, however, is overcome if we consider that the introduction of the anal plate into the ring of radials necessitated corresponding modifications among the basals, as otherwise these plates would lose their interradial position. It required either the introduction of a basi-anal plate, or an increase in the size of the original pieces. That the latter occurred among the Camerata is clearly shown by the diagrams, and the evidence leaves no doubt at what part of the base the extra width was inserted.

Taking first the quadripartite base, and comparing Fig. 2 of the diagrams with Fig. 8 — one pentangular and the other hexangular — we find that in the latter the posterior basal has doubled in size (Fig. 7), without materially changing the orientation of the plates, or disturbing their general arrangement.

In the tripartite base the change was accomplished in a different way. There $x$ is added to plate $c$ (Figs. 9 and 10), and the plates $ab$ and $cd$ have coalesced, and hold relatively the same position as in Fig. 3.

The bipartite base is probably derived from the tripartite (Fig. 4), which preceded it in time, and $x$, which in the latter constituted a part of $c$, is united with $cd$, and $ab$ with $c$ (Figs. 11 and 12).

Now, taking up Fig. 7, and eliminating $x$, so that the side of plate $a$ rests against the plate $c$, we obtain Fig. 2, and by a similar procedure we are enabled to transform Fig. 9 into Fig. 3. The hexagonal base is thus restored to its primitive pentagonal form without disturbing the orientation of any plate, compound or simple.

A most beautiful confirmation of these observations is furnished by an abnormal specimen of *Teleiocrinus umbrosus* in our collection, in which the regular anal plate is wanting. *Teleiocrinus* has normally three equal basals, but in this specimen the basal plate to the left of the anterior ray is reduced to one half its normal size, leaving the basal disk exactly like that of forms which are normally without the anal plate.

It is very remarkable that while in all Crinoids with an unequally tripartite, monocyclic base, the smaller plate is located to the *left* of the anterior radial, this plate in the base of the Blastoids lies invariably to the *right* (Fig. 6).

Among monocyclic Inadunata, in most of the genera, the changes among the basals are not so readily traced as in the Camerata, owing to the asymmetry of the radials, which more or less affected the form of the basals. Most of them have five basals, but there are some genera with three and four. *Anomalocrinus*, so remarkable for its asymmetry, has five basals, but there is frequently a small additional plate interposed beneath the extremely large left posterior radial. As this plate is only occasionally represented, it is probably not of much morphological importance. *Storthingocrinus* and *Symbathocrinus* have three unequal basals, arranged like those of the Platycrinidæ. The Calceocrinidæ have three or four basals of a decidedly irregular arrangement. *Belemnocrinus* is the only known monocyclic genus with five basals in which the regular anal plate is represented; but the plate is quite narrow, and affects but slightly the symmetry of the plates of the proximal ring. In the Hybocrinidæ, a large radianal is interposed between the radials, and the basals consist of five plates of a rather irregular form.

That the smaller number of basals is a modification of the original five plates, is indirectly shown by the fact that in many species of *Platycrinus* the plates are so closely anchylosed that no vestige of suture lines can be seen. In some of them the lines are marked by grooves, while in others even the sutures are plainly visible. The sutures are always better defined in a young specimen than in the adult, and in some species can be seen the outlines not only of three, but of five plates. It is further significant that in all *Platycrini* of the Warsaw and St. Louis groups, the suture lines are elevated, and transformed into ridges by excessive deposit of limestone matter.

The case of *Pisocrinus* is very interesting. The Silurian species plainly show five basals, while those from the Devonian of the Eifel, which have been referred by Schultze to *Triacrinus*, very often have but three. A careful examination of a large number of Eifel specimens leaves not the least doubt that in some of them there are still five plates, while in others of the same species the number is reduced by anchylosis to three. Among recent Crinoids also, Carpenter and others have noticed a fusion of the basals in

*Hyocrinus* and *Rhizocrinus*, and it is possible that the former has really but three basals; but in *Rhizocrinus* the fusion was not complete, as Count Pourtalès proved by inserting a needle in the central canal, whereupon the base separated into five pieces.*

The foregoing facts are of considerable importance as to classification. For if the smaller number of plates is merely a modification of the original five, the number of basals cannot be regarded as a good character for separating the Crinoids into primary groups, as was practically done by Angelin, and afterwards by S. A. Miller.

The basals of dicyclic Crinoids, as we have stated, invariably consist of five pieces, but their form differs in different groups. In the Rhodocrinidæ (Fig. 17) they are all heptagonal; while in the Thysanocrinidæ the posterior one is heptagonal, and the four others hexagonal (Fig. 18) — the former supporting a supplementary plate at each interradius, the latter at the anal side only. In the Fistulata, all five plates are hexagonal when there is no anal plate, as in the Encrinidæ; but in the Cyathocrinidæ, whenever that plate is represented, four of the basals are hexagonal, and the fifth heptagonal, precisely as in the Thysanocrinidæ. In the Poteriocrinidæ, and all other families in which in addition to the regular anal plate a radianal is represented, only three of the basals are hexagonal, and the posterior and right postero-lateral basals are heptagonal (Figs. 15 and 16).

The same variations occur among the basals of the Ichthyocrinidæ. Those of *Ichthyocrinus* agree with the basals of the Encrinidæ; those of *Mespilocrinus*, *Taxocrinus*, *Forbesiocrinus*, and *Calpiocrinus*, with the plates of the Cyathocrinidæ; while the basals of *Lecanocrinus*, *Gnorimocrinus* and *Sagenocrinus* are in a similar condition to those of the Poteriocrinidæ.

Three infrabasals have been observed only among the Fistulata and Articulata. They are represented sparingly among the former, but are the rule among the Ichthyocrinidæ, and are represented in the larva of the Comatulæ. Wherever they occur, they consist of two large plates and a smaller one, which are differently arranged in the various groups. In the Fistulata, according to Bather, the position of the small plate is not constant; we have always found it located anteriorly below the suture between the two anterior basals, and the plates *f* and *g* and *i* and *k* fused together (Fig. 16). In the Ichthyocrinidæ, however, the small plate rests below the suture between the posterior and right postero-lateral basal, and *f* and *g* and

* Memoirs Mus. Comp. Zoöl., Vol. IV., p. 29.

*h* and *i*, respectively, are united (Fig 13). As this structure is apparently constant in the latter group, we regard it as of some importance as regards classification.

The introduction of the anal plate did not affect the basals of dicyclic Crinoids in the same manner as in the monocyclic. While in the latter, when the plate is represented, the orientation of the basals is slightly disturbed, in the dicyclic forms it remains unaltered. The anal plate of the latter rests invariably upon the truncated upper face of the posterior basal (see Figs. 14 to 18); while in monocyclic Crinoids it is supported by the basals *a* and *e* (Figs. 10 and 12), or occasionally by *a* and *x* (Fig. 8).

The infrabasals are completely anchylosed in the Cupressocrinidæ, Gasterocomidæ, and in *Stemmatocrinus*, where they form an undivided disk, which Carpenter and others have regarded as representing the top stem joint, as in the case of the Apiocrinidæ and Comatulæ. *Agassizocrinus*, in its pedunculate younger state, had five well defined infrabasals; but after losing its stem, the suture lines became gradually obliterated by limestone deposit upon the surface. The same is the case with the basals of the monocyclic *Edriocrinus*.

Mr. Bather discriminates between Dicyclica, Pseudomonocyclica, and Monocyclica vera.* To the Pseudomonocyclica he refers those forms in which infrabasals are obsolete in the adult, but were represented in early life. They embrace most of the Mesozoic and recent Crinoids, and may be subdivided into two classes: (1) forms in which the infrabasals gradually become anchylosed with the top stem joint, and (2) those in which they were resorbed in the adult. In the former, which among other groups include the Apiocrinidæ and Comatulæ, the new stem joints are formed below the centro-dorsal; while in the latter, which are typified by the Pentacrinidæ, the top stem joint is the youngest joint of the stem. We shall presently show that both these forms, although the infrabasals may have disappeared, still retain the characteristics of dicyclic Crinoids.

Several years ago we discovered † that among the Palæocrinoidea there is a regular alternation in the arrangement of the successive parts below the radials, and that the orientation of the stem is essentially different among monocyclic and dicyclic forms. We found that the salient angles of the stem itself, and the projections of the axial canal, are reversed in the two groups,

* Ann. and Mag. of Nat. Hist. (sixth series), Vol. V., April, 1890, p. 316.

† Revision, Part III, Section 1, p. 7 (Proceed. Phila. Acad., 1885, p. 229), with a most unfortunate transposition of terms, which was corrected in the appendix. Also 1888, Proceed. Phila. Acad. p. 351.

and that the cirri, which in dicyclic Crinoids are radial, are interradial in the others. By employing this rule we were enabled, in many cases where the infrabasals are hidden beneath the column, to determine their presence. The law of alternate arrangement of the successive parts is shown by the following table: —

| | | | Dicyclic. | Monocyclic. |
|---|---|---|---|---|
| 1. | Basals. | | Interradial. | Interradial. |
| 2. | Infrabasals. | | Radial. | |
| 3. | Column. | Exterior angles of. | Interradial. | Radial. |
| | | Sections of. | Interradial. | Radial. |
| 4. | Column. | Sutures. | Radial. | Interradial. |
| | | Sides. | Radial. | Interradial. |
| | | Cirri, when present. | Radial. | Interradial. |
| | | Axial canal. | Radial. | Interradial. |

This law is only applicable, to its full extent, in species with pentangular or pentapartite stem and canal; but we infer, from analogy of these forms, that the circular stem, wherever it occurs in dicyclic Crinoids, is also practically interradial, and in those of monocyclic type radial. Our observations were founded upon Palæozoic Crinoids, among which we had met with no exception; but on applying them to Mesozoic and later Crinoids, we were surprised to find that in most of the so-called monocyclic forms the relative positions of the column and cirri were reversed, so that they were exactly as in dicyclic Palæocrinoids. Though universally considered to be monocyclic Crinoids, they were built on a dicyclic plan; and this led us to inquire whether all those forms might not be dicyclic, whose infrabasals were hidden, or had existed in their larval state.

This seemed to be confirmed by another observation which we made among certain Palæozoic forms. In some genera, notably in *Graphiocrinus*, which was originally described as monocyclic, the infrabasals are so extremely small that they are completely covered by the upper stem joint, and only the basals are visible. These Crinoids are practically in the same condition as *Millericrinus*, *Apiocrinus*, and *Pentacrinus*, for the stem occupies the same position toward the proximal ring of plates visible in the calyx as that of *Millericrinus* and *Apiocrinus*, except that in the two latter the space above the top stem joint is vacant, while in *Graphiocrinus* it is filled by very small infrabasals (compare Fig. 17 with Fig. 20 on Table A).

Small infrabasals are known to exist in the base of the Pentacrinoid genus *Extracrinus*, and de Loriol has discovered similar plates in two species of *Millericrinus* (Plate VI. Figs. 1 *a*, *b*, and 2 *a*, *b*). Those of *M. polydactylus* he describes as follows: * "Je distingue très nettement, sur deux individus, cinq pièces extrêmement petites, à peine distinctes à l'œil nu, qui sont logées au centre de l'article basal, chacune reposant sur le sommet de l'une des carènes, dans une direction radiale, au centre se trouve, une petite dépression qui forme le fond de la cavité. Ces petites pièces, que je n'avais jamais encore observées, jouent évidemment le rôle de pièces infrabasales, mais à l'état tout à fait rudimentaire." Similar pieces were discovered by him in his *M. Orbignyi*, of which he says: † "Elles ne peuvent absolument se voir que lorsque, par un hasard heureux, l'article basal peut se dégager du calice. Il me paraît indubitable que se sont là de petites pièces infrabasales rudimentaires semblables à celles que j'ai signalées dans le *M. polydactylus*."

Admitting these plates to be infrabasals, it is certainly quite improbable that other species of *Millericrinus* having a pentangular stem, and those with a round stem, and the species of *Apiocrinus*,—a genus which, according to de Loriol, is very closely allied to *Millericrinus* and *Guettardicrinus* — should have possessed no infrabasals. In all species of *Millericrinus*, the column, unless it is round, has interradial angles (Plate VI. Figs. 1$^a$, 3, 4$^b$, 5), exactly as in *M. Orbignyi* and all dicyclic Palæocrinoids; and hence, if the genus were not dicyclic, this structure would be at variance with that of other Crinoids. We come to the same result if we examine the vacant space within the basal ring. This is radial, and disproportionate in size to the axial canal of the stem, which is small and circular; whereas if it represented the axial canal of a monocyclic Crinoid it should be interradial. The space is large enough to have contained, besides the canal, additional plates, which, if present, would have occupied the same position as the infrabasals of *M. Orbignyi*.

The column of dicyclic Crinoids abuts either entirely against the infrabasals, or partly also against the basals. The latter is the case with the top

* Paléont. Franç., 1$^{re}$ série, Animaux Invertébrés, Terr. Jurassic, Tome XI. Première Partie, Crinoides, Paris, 1882–1884, p. 553, Plate 110. Figs. 1 and 2.

† Ibid., p. 566 (Plate 116, Fig. 1, *b*, *c*, *d*).

stem joint of *Millericrinus Orbignyi* and *M. polydactylus;* while in other species of the Apiocrinidæ in which infrabasals are unrepresented, the column touches the basals only. It rests against the *outer* (dorsal) surface of the plates, whose *lower* margins are bent up, so as to form an inverted pentangular concavity, radially disposed. This cavity, which is occupied and completely filled by the top stem joint, is generally grooved at the interbasal sutures, and produces upon the upper face of the joint five angles, which fit into the grooves, and interlock with the basals (Plate VI. Figs. 1 *a*, 1 *b*, and 5). The outer edge of the joint at the upper end has also a more or less radial outline; while its lower end follows the orientation of the stem, and is interradially disposed when that is pentangular.

We mention these particulars, because Carpenter, in criticising our generalization,* undertook to prove by the angularities at the upper face of the stem that in those species of the Apiocrinidæ in which the stem is round, the latter was radially disposed, and not interradially; and that those species, according to our own rules, were monocyclic and not dicyclic. He overlooked the fact that the top joint rests against the turned up *dorsal* (outer) *surface* of the basals, and not against their *inferior faces.* The surface to which the "centro-dorsal" is attached, represents morphologically the surface of the concavity for the reception of the column in Palæozoic Crinoids; the inferior faces are those which meet the infrabasals, and in *M. Orbignyi* and *M. polydactylus* actually support them, but in most of the Apiocrinidæ they enclose a vacant space. If this space was filled by infrabasals, as we think it was in the young Crinoid, the columnar concavity and the upper face of the stem would be in exactly the same condition as in the Ichthyocrinidæ, in which similar angularities occur on the upper face of the stem (Plate II. Fig. 4*b*). The upper face of the column in all Crinoids adapts its form to the shape of the plates to which it is attached, and if their suture lines are grooved, it will be correspondingly ridged. We thus believe that Carpenter misunderstood the structure, and that he overlooked our statement that it is the longitudinal angles *along the column* which alternate with the proximal ring of plates in the calyx, and not the angularities or ridges *of the upper face.*

In *Rhizocrinus* the condition of the base is apparently similar to that of the Apiocrinidæ. The genus, however, was described by Carpenter† as

* Ann. and Mag. Nat. Hist., March, 1886, p. 286.
† Chall. Rep. Stalk. Crin., p 246.

monocyclic, and the uppermost stem joint as the last formed plate of the stem. But he seems to have changed his opinion afterwards, for in a letter to us, dated November 28, 1890, he writes as follows: "I have spent this morning studying my material of *Rhizocrinus*, including some fresh specimens which I found among my father's collection, and I conclude that you are right in considering the top-stem-joint as a centro-dorsal like that of *Bourgueticrinus* and the Apiocrinidæ. It is, however, always the smallest, *i. e.*, thinnest joint of the stem. But it is distinctly marked into five fossæ for the basals by radial ridges, and this is sometimes very apparent in the younger individuals. See Chall. Rep. Plate X. Figs. 7 and 8. It is more marked in *R. Rawsoni* than in *R. lofotensis*. The pentagonal space in the centre. Plate X. Fig. 5, is nothing but the axial canal." He then continues; "*Bathycrinus* is a very different form, with its very numerous thin joints at the top of the stem (see Plates VII. and VIII *a*), and I have been thinking for some time past that it must be removed from the Bourgueticrinidæ and made the type of a new family. The ten arms, and the trifascial articulation are also good characters, as the latter replaces the syzygies of *Rhizocrinus*."

Except in one point, we fully agree with this. Examining Plate X of the Challenger Report, we find in *Rhizocrinus* the space within the basal ring very different from the axial canal in the stem joints (see our Plate VI. Figs. 7*a*, *b*), the former being fully twice as large, and pentangular, while the canal is oval. The space between the basals is radially disposed, as in the Apiocrinidæ, and we believe that *Rhizocrinus* is also pseudomonocyclic. Its structure is altogether different from that of *Bathycrinus* and *Hyocrinus*, which in our opinion are true monocyclic forms. They have no centro-dorsal, and the uppermost joint is the last formed plate of the stem. The open space within the basal ring is interradially disposed, and has the form and size of the stem canal.

Our observations on the Apiocrinidæ led us in 1885* to the conclusion that most of the Neocrinoidea may have possessed rudimentary infrabasals in their larval state. This rather startling statement was unfavorably received by Carpenter, and severely criticised by him.† He held at that time that with the exception of *Encrinus*, *Extracrinus*, *Marsupites* and *Uintacrinus*, all Mesozoic and recent Crinoids were monocyclic. His objections, however, did not seem to us convincing, and in Section II. Part III. of the Revision, pp. 294-

* Revision, Part III., Section I., pp. 8, 71.
† Bibliogr. Notices. Ann. and Mag., November, 1886, p. 408.

299, we asserted that not only the majority of Stalked Crinoids, but also the Comatulæ, were built upon the dicyclic plan, and probably had infrabasals in their larval state.

The centro-dorsal at the Pentacrinoid stage of the Comatulæ, as may be seen by examining Plate VI. Figs. 18 and 19, agrees closely with that of the Apiocrinidæ. It is interradially disposed at the proximal face, and also at the distal face, so that its angles correspond with the angles of the basals, as in those dicyclic Crinoids whose infrabasals are hidden by the column; and even in its free floating stage the centro-dorsal retains its interradial position.

So strongly were we impressed with the conviction that the Comatulæ are dicyclic Crinoids, — although no traces of infrabasals had ever been found by Wyville Thomson, the two Carpenters, Goette, and others who had extensively studied the embryology of *Antedon,* — that we urged European investigators to make fresh search for these plates.

It was therefore with no little satisfaction that we learned from Dr. Carpenter in July, 1887, that infrabasals, whose existence we had predicated upon palæontological evidence, had actually been found by Mr. H. Bury. This important discovery was announced at the Manchester meeting of the British Association, and communicated by Mr. Bury in a paper on "The early stages in the Development of *Antedon rosacea.*" * The plates appear in the ciliated larva, and consist of three unequal pieces, which in the Pentacrinoid stage are fused together with the top-stem-joint (centro-dorsal), so as to form together with the latter one large plate, with five angles, radial in position. One of the plates is smaller, and has but one salient angle, the two larger ones having two, — a structure which suggests that the two latter may represent a pair of anchylosed plates. Three similar plates, but with a somewhat different orientation, persist throughout life in the Ichthyocrinidæ, but the smaller plate of *Antedon rosacea,* if we understand Mr. Bury, is placed anteriorly; while that of the Ichthyocrinidæ is directed posteriorly (Table A, Figs. 14 and 15).†

It is of considerable importance that the infrabasals of all Carboniferous Ichthyocrinidæ are coalesced with the top-stem-joint (centro-dorsal) similar to those of *Antedon.* In specimens in which the column has been detached from the crown, the small infrabasals generally adhere to the top-stem-joint

* Philosophical Transactions of the Royal Society of London, 1888, pp. 257–300.

† The orientation of this plate was incorrectly given by us in the Revision, Part III. Plate 6, Fig. 23. Since then we have found out that it is located in all Ichthyocrinidæ to the right of the posterior basal.

(Plate II. Fig. 4 *b*), being in some cases perfectly fused with that plate (Plate VI. Fig. 11). The condition is the same as in the two species of *Millericrinus* in which infrabasals have been recognized, and we conclude from analogy that a fusion of those plates eventually took place in all groups in which the new stem joints are not formed directly beneath the calyx.

The case is different among the Pentacrinidæ, in which the new stem joints constitute the upper part of the stem. Of the principal genera which have been referred to this family, one — *Extracrinus* — has small infrabasals persistent through life; while in the other two — *Pentacrinus* and *Metacrinus* — no trace of them can be found in the adult. The dicyclic nature of *Pentacrinus* and *Metacrinus* is indicated by the orientation of the stem and cirri, the angles of the stem in both of them being interradially disposed, and the cirri radially. But what became of their infrabasals? That they fused with the upper stem joint, like those of the Ichthyocrinidæ, need not be considered in this family, as that would necessarily prevent the formation of new joints at the top. They may have been resorbed in the growing animal; but it appears to us more probable, from palæontological evidence, that the plates gradually diminished in size, and finally disappeared altogether in the group. The structure of the Pentacrinidæ is very different from that of the Comatulæ and Apiocrinidæ, and it appears to us that Crinoids in which the upper joint of the stem is the youngest, cannot be derived from those in which the top of the stem is fused with the infrabasals, and the two groups should be widely separated. The Apiocrinidæ and Comatulæ which have a centro-dorsal,— *i. e.*, in which the infrabasals are fused with the upper stem joint, — should be placed together with, or close to, the Ichthyocrinidæ; while the Pentacrinidæ, which in many points agree with the structure of the Poteriocrinidæ and Encrinidæ, we think might be safely referred to the Inadunata Fistulata.

It is very singular that while in *Extracrinus* and *Metacrinus* the projections of the open space within the basal ring, and the axial canal of the stem, are radially disposed (Plate VI. Fig. 9), both are decidedly interradial in *Pentacrinus* (Plate VI. Fig. 8). This anomaly, if we may so call it, was regarded by Carpenter * as a proof that our generalization upon the stem is not applicable to the Neocrinoids. This, indeed, seemed at first to be indicated also by the orientation of the stem; but Bury's discovery of infrabasals in the Comatula larva changed the whole aspect of the case. The discovery of these plates,

* Bibliogr. Notices, Ann. and Mag. Nat. Hist., March, 1886, p. 287.

whose presence we had inferred from the orientation of the larval stem and centro-dorsal, showed that our observation must be one of wide significance. The aberrant structure of the canal in *Pentacrinus* does not invalidate the law as we have found it, but simply points to the existence in some groups of transition forms intermediate between Monocyclica and Dicyclica. Such transition forms must have occurred at some time in the developmental history of the two groups, if one was evolved from the other. Which form is the older has not been satisfactorily proved, but the evidence of Palæontology points to the Dicyclica as the ancestral type. In the Camerata the evolution was apparently complete at and before the Silurian, but it is probably still going on in some of the later groups. In the Pentacrinidæ, the diminutive size of the infrabasals in *Extracrinus* may be the first step toward the monocyclic base, their non-representation in *Metacrinus* and *Pentacrinus* the next, and the change in the orientation of the axial canal another important step in that direction.

We have discovered a case almost parallel to that of the Pentacrinidæ in the Lower Silurian monocyclic genus *Glyptocrinus*, which has a radial stem* and an interradial canal, except in *G. Fornshelli*, in which canal and stem both are radial (Plate XXI. Fig. 5).

*Glyptocrinus* belongs to a series of monocyclic and dicyclic Crinoids, which are so closely intermingled and intimately related that it is extremely difficult to separate them generically, and one is inclined to place in the same family monocyclic and dicyclic forms. There is perhaps no other group so likely to throw light upon the derivation of the Monocyclica. The base of *Glyptocrinus* has been variously described as consisting of one or two rings of plates. Hall originally defined the genus as having basals only, but a few years later thought he had discovered within the basal ring in some of the species indications of five additional pieces, which were also observed by Meek, and called by him "sub-basals" (Plate VI. Fig. 12). S. A. Miller described the base as consisting of but one ring of plates, but he included in the genus several species with two rings. We described the genus as dicyclic in Part II. of the Revision, but in Part III. placed it among the Melocrinidæ, after throwing out those species in which rudimentary infrabasals could be satisfactorily traced.

* The nucleus of the stem in *G. decadactylus* and *G. Dyeri* is obscurely pentangular at the upper end; the projecting edges of the joints, however, give it a circular outline. The axial canal in both species is sharply stellate.

The case of *Glyptocrinus Fornshelli* is very remarkable. The orientation of the stem points to a monocyclic base, that of the axial canal to a dicyclic. Besides, the species is closely related to others in which the canal is interradial, and the stem radial. It is quite evident that the rule which governs the relations of the parts below the base does not hold good in *G. Fornshelli*, as we find it in the fossil state; but we think this proves nothing more than that in this species the monocyclic stage was as yet incompletely developed. It should be stated that while the aberrant canal of *G. Fornshelli* is radial throughout the whole length of the stem, that of *Pentacrinus* is interradial only at the upper portions; it soon turns to circular, and where the cirrus vessels enter, it is as radially disposed as that of *Metacrinus*.

Among the Reteocrinidæ, also, a strictly Silurian family, we find a variety of transition forms. In *Reteocrinus* the species from the Trenton group have large infrabasals, those from the Hudson River group quite rudimentary ones; while in *Xenocrinus* and *Tanaocrinus* the infrabasals are altogether unrepresented. The axial canal of *Reteocrinus* is radially disposed, that of *Xenocrinus* and *Tanaocrinus* interradially. The three forms are very closely related, and if we were to separate them upon the structure of the base, it would be to the exclusion of other characters of manifest importance.

The examples given indicate that there is a most intimate relation between dicyclic and monocyclic forms, and that probably the latter were derived from the Dicyclica by a gradual decrease in size and final obliteration of the infrabasals in geological time.

Bather believes with us that dicyclic Crinoids preceded the monocyclic, but he states that so far as the Fistulata are concerned he has found no geological evidence to prove it, at least not among the Fistulata. He alludes to the Hybocrinidæ as being probably monocyclic, but he regards the Heterocrinidæ and Anomalocrinidæ as true Monocyclica. As to *Hybocrinus*, he quotes the earlier part of the Revision, in which we stated that rudimentary infrabasals might possibly be present in the genus. This supposition is not verified by further study of the specimens, which show satisfactorily that no such plates are represented. *Hybocrinus* is a true monocyclic genus, as much so as *Heterocrinus* and *Anomalocrinus*. This, however, does not exclude the idea that all three forms may have been derived from the Dicyclica, and there are good reasons to believe that it was so. The dicyclic pseudo-cystid genus *Porocrinus* is so intimately related with *Hybocrinus* that it is doubtful if the two should not be placed in the same family. Close relations also exist between *Merocrinus* and *Iocrinus*, and between *Ottawacrinus* and *Heterocrinus*,— dicyclic and monocyclic forms respectively.

While the evidence thus points to the probability that the one group was derived from the other, it is difficult to explain the change in the orientation of the stem. That the whole crown passed through a revolution of 36° is highly improbable. The change probably took place in the body of the stem, modifying its form to suit the condition of the base. The stem is round in most of the earlier Crinoids; but we find occasionally within the same family quadrangular stems from a quadripartite base, together with pentangular stems from a quinquepartite base, which goes to prove that the stem, to some extent at least, adapted its form to the conditions of the base. In a similar manner interradial stems may have changed into round stems, and these into radial stems. This, however, does not explain the change in the orientation of the canal, and that of the cirri. The latter are directed to the angles of the axial canal, through which they communicate with the chambered organ.

The only writer, besides Bather, who has discussed the derivation of the two groups is Dr. J. Walther,* who takes it for granted that the simpler— monocyclic—form is the ancestral one. His arguments were suggested from his study of the pentacrinoid larva of *Antedon*, and are extremely hypothetical. They are based upon his peculiar interpretation of the basals and infrabasals, which, as he now will himself admit, cannot be upheld since Bury discovered infrabasals in the larva of *Antedon*.

## C. *The Radials.*

The term "radials" is applied by us only to the first plate of each ray. All succeeding plates in a radial direction, whether free or incorporated into the calyx, are brachials. The name was given by Müller to all plates up to, and including the first axillary, and all pieces beyond were regarded by him as armplates. The same view was taken by Roemer, de Koninck, and other European authors. The American Palæontologists applied the term not only to the plates of the first order, but to all plates of the rays that take part in the calyx. They distinguished those of different orders as primary, secondary, and tertiary radials, according to rank.

* "Untersuchungen über den Bau der Crinoideen." Palæontographia, 1866, Bd. XXXII., pp. 180-199.

Müller's interpretation of these plates was somewhat modified by Schultze,* who assumed that the arms begin invariably with the first well-defined articular facet. He held that in *Actinocrinus* and *Rhodocrinus*, which have no articulation above the (first) radials, the arms commence above the first axillary; but that in Crinoids in which the rays are free above the first plate, the arms begin with the second plate of the ray.

Zittel,† who accepted Schultze's views and applied them to the later Crinoids, describes *Encrinus*, *Pentacrinus*, and *Millericrinus* with one radial followed by two brachials; *Apiocrinus*, however, with three radials. He evidently supposed that in the latter the first articulation occurred on the axillary, which is not the case, as shown by Carpenter,‡ who found in several species of that genus at the upper face of the (first) radial a transverse ridge with muscular fossæ above it. A similar structure, he believes, exists in all Apiocrinidæ, perhaps with the exception of *Guettardicrinus*, which, according to de Loriol,§ has no articular facets on either of the three "radials," nor even on the distal faces of the axillary, so that it cannot be determined in this genus what plate of the ray bears the first facet. This shows that Schultze's rule does not readily apply in this group. Still more serious difficulties arise among the Palæocrinoidea. In most of the Camerata, all plates of the calyx up to the top of the distichals, and often much higher, are closely and immovably united, and the lowest articulation or mobility occurs at the base of the arms.

Applying Schultze's definition to the Camerata, it is quite evident that all the plates of the dorsal cup in a radial direction had to be called radials, and not merely those up to the first axillary. This we did in our earlier writings; and instead of making the lower facet the division between radials and brachials, we took the calyx for the boundary line, and referred to the radials all plates of the rays which take part in the calyx, and to the brachials the plates of the free arms. We thus recognized among the Camerata an indefinite number of radials, while their number was reduced in the Inadunata to a single ring of plates, a course which was afterwards adopted by S. A. Miller, S. H. Williams, and Prof. Worthen, against Hall, Meek, and others, who included in this group the first order of brachials.

The Ichthyocrinidæ, in which the lower branches of the rays take part

* "Monographie der Echinodermen des Eifler Kalkes," 1866, Wien, pp. 5 und 9.
† Handbuch der Palæontologie, Vol. I., p. 339.
‡ Ann. and Mag. Nat. Hist., Ser. 6, Vol. VI., p. 12.
§ "Paléontologie Française, Jurassique," Tome XI., Pt. I., p. 215.

in the calyx, were treated by us in the same way as the Camerata. Schultze, however, described *Taxocrinus* as having but one radial, in which he was correct from his standpoint, for the succeeding plates seem to be united among themselves, and with the radials by loose suture or a sort of rudimentary articulation. Carpenter described *Pentacrinus* and the Comatulæ, which are in a similar condition to the Ichthyocrinidæ, as having three radials in all cases, whether the plates are enclosed by perisome or not, and he distinguished the rami as primary, secondary, and tertiary arms. According to him, *Rhizocrinus Rawsoni*, with ten arms, has three radials; while *R. lofotensis*, like *Cupressocrinus*, *Pisocrinus*, and all Crinoids with but five arms, have one radial, followed by brachials. He thus made the second plate of the ray a *second radial* in the former, and a *first brachial* in the latter, giving to parts which are undoubtedly homologous different appellations, while distinct parts were thrown together. The methods of treating these plates heretofore adopted were not only empirical, but inconsistent with the principles of morphology; and the want of uniformity among the different writers, respecting the terms, must have been perplexing to the student when consulting their works.

In 1881,* and again in 1885,† we expressed the opinion that the arms fundamentally begin with the second plate of the ray, and that all Crinoids have but one ring of radials. In support of this we stated that only the lower ring could be homologized with the oculars of other Echinoderms; that in the simpler form — the Inadunata — the arms were free from the (first) radials, and that in the remaining groups the lower arm plates were incorporated gradually in palæontological time. We refrained, however, at that time from changing the terminology, finding it convenient for purposes of description to continue the old terms.

Our interpretation of the plates was accepted by Carpenter in 1884,‡ who confirmed it by the developmental history of the plates. The "outer radials," he says, "commence as imperfect rings, which soon become filled up with lengthening fasciculated tissue, just as is the case with the stem joints and later brachials;" but "the *first* radials, like the basals and orals, commence as expanded cribiform films." He further alluded to the fact that the so-called primary radials of *Metacrinus* are pinnule-bearing, — a thing which we have observed in exceptional cases among the Poteriocrinidæ also.

* Revision, Part II., p. 10. † Ibid., Part III. p. 12.
‡ Challenger Rep. on the Stalked Crinoids, p. 48.

Upon commencing the present work, we had an interchange of views with Dr. Carpenter as to the best plan to be pursued respecting these plates, especially as to whether it would not be better to change their terms, which we considered meaningless from a morphological point of view, for others more appropriate. We proposed to restrict the term "radials" to the first ring of plates of the rays, and apply to the succeeding ones the terms "primary," "secondary" and "tertiary brachials," according to their rank, in all cases, whether the plates were free or not. He replied that he appreciated the great advantages of the proposed nomenclature, and was willing to adopt it in principle; but he thought the terms "primary," "secondary," and "tertiary brachials" were too long and cumbrous, and he proposed instead of them the terms "costals," "distichals" and "palmars," respectively; which we finally agreed to accept. Carpenter announced our agreement in a paper "On certain Points in the Anatomical Nomenclature of Echinoderms." *

In the earlier Inadunata and Articulata, — not in the Camerata so far as observed, — the radials are frequently compound, *i. e.*, constructed of two segments or parts, which are closely united by a horizontal suture, and in the organization of the Crinoid count as one plate.† Among the Fistulata, compound radials are found in the Heterocrinidæ, Anomalocrinidæ, Hybocrinidæ and Dendrocrinidæ. In some of these families they are restricted to the right posterior ray, in others they occur also in other rays. We know of no case in which the compound structure extends to all five radials, at least two of the plates being always simple. Among the Heterocrinidæ, as a rule, the right posterior, and the right and left antero-lateral radials, are compound, — exceptionally the anterior one in place of the left antero-lateral; — while *Anomalocrinus* and *Ohiocrinus* have but two, and *Iocrinus, Merocrinus, Hybocrinus* and *Hoplocrinus* only one. It is further worthy of note, that when there are several compound radials, the corresponding parts are of nearly equal size; while the segments vary considerably among themselves in the different genera. In *Heterocrinus, Ohiocrinus, Iocrinus, Merocrinus, Hybocrinus* and *Hybocystis*, the lower portion, — the so-called inferradials, — are considerably larger than the upper or superradials. In *Anomalocrinus* and *Dendrocrinus* the two plates are of nearly equal size; while in *Ectenocrinus* (*Heterocrinus*) *simplex* the upper ones are three or four times as large as the lower. In

* Ann. and Mag. Nat. Hist., Ser. 6, Vol. VI., pp. 11-18.

† We gave a full description of these plates in a paper "On the Perisomic Plates," Proceed. Acad. Nat. Sci. Phila., October, 1890, pp. 378 and 379.

*Anomalocrinus* the left posterior radial, which is the largest plate in the calyx, is sometimes bisected longitudinally, but this is not constant.

The gradual increase in size of the upper segments, and the disappearance of compound plates in other rays than the posterior, indicates that in these Crinoids there is a transition from three compound plates to one, and also from compound to simple plates; and we think it may be safely assumed that there was a time in the early history of the Crinoids when the arm-bearing section was altogether unrepresented. This was apparently the case in *Baerocrinus*, in which two of the radial plates are non-arm-bearing, and as these plates occur in the same rays as the compound plates of *Anomalocrinus*, we may infer that *Baerocrinus* is the ancestral form, lower in its development than either *Anomalocrinus*, *Hoplocrinus* or *Iocrinus*.

The later Fistulata have no true compound radials; and although the lower segment of the posterior radial is still represented in many of them, that plate does not bear the same relation to the arm-bearing plate that it did in the earlier forms, but assumes the functions of an anal plate. As such, it will be considered by us in its proper place.

Among the Larviformia, true compound radials occur in *Haplocrinus*, which has three of them: in the right posterior, and the right and left antero-lateral rays, — the same rays in which they occur in the Heterocrinidæ. The compound plates of the Ichthyocrinidæ will be discussed in connection with the anal plates.

In groups in which the radials are simple, the five plates are approximately of the same size; but when compound, they often differ considerably in size and form. This is most apparent in *Calceocrinus*, *Catillocrinus*, *Haplocrinus*, and *Pisocrinus*. Among the Poteriocrinidæ also, when the inferradial is represented, the right posterior one is smaller than the others, and of somewhat different form. In some Palaeocrinoidea, the radials are separated by supplementary plates; while in all later Crinoids, with the exception of the recent genus *Thaumatocrinus*, they are in contact all round. In the Rhodocrinidæ, and curiously enough in *Thaumatocrinus*, they alternate with large interradial plates, with which they form a ring of ten pieces. In the Thysanocrinidæ, Actinocrinidæ, Batocrinidæ, Acrocrinidæ, Dichocrinidæ, and in most of the Fistulata and Ichthyocrinidæ, a special anal plate is interposed between the two posterior radials. In the Reteocrinidæ, they are separated by numerous small, ill-defined plates at the four regular sides, with the addition of an anal plate at the posterior side. In the Melocrinidæ, Eucalyptocrinidæ, Platycrinidæ, and in a few of the later Fistulata, all five radials are in contact laterally.

The radials, both among each other and with the basals, are united by close suture, the apposed faces being generally smooth, but occasionally wrinkled or striated.

### D. *The Arms and Pinnules.*

Admitting that the arms begin with the first plate above the radials, all plates of the rays, from the second one up, are brachials. As before stated, we adopt the terms costals, distichals, and palmars, for the first, second, and third order of brachials, respectively. When there are further divisions in the rays, the plates are designated as postpalmars, or, when greater detail is required, as brachials of the fourth, or fifth, order, and so on. We also discriminate between fixed and free brachials, meaning by "fixed" that the plates so designated take part in the formation of the calyx, and by "free" that they do not.*

* This is a slight modification of the plan proposed by Carpenter, who reserved the term "*free brachials*" for the plates of the terminal branches alone. He also differed from us in calling the postpalmars, when there are more than four bifurcations to the ray, "*postpalmars* of the first, second, or third order."

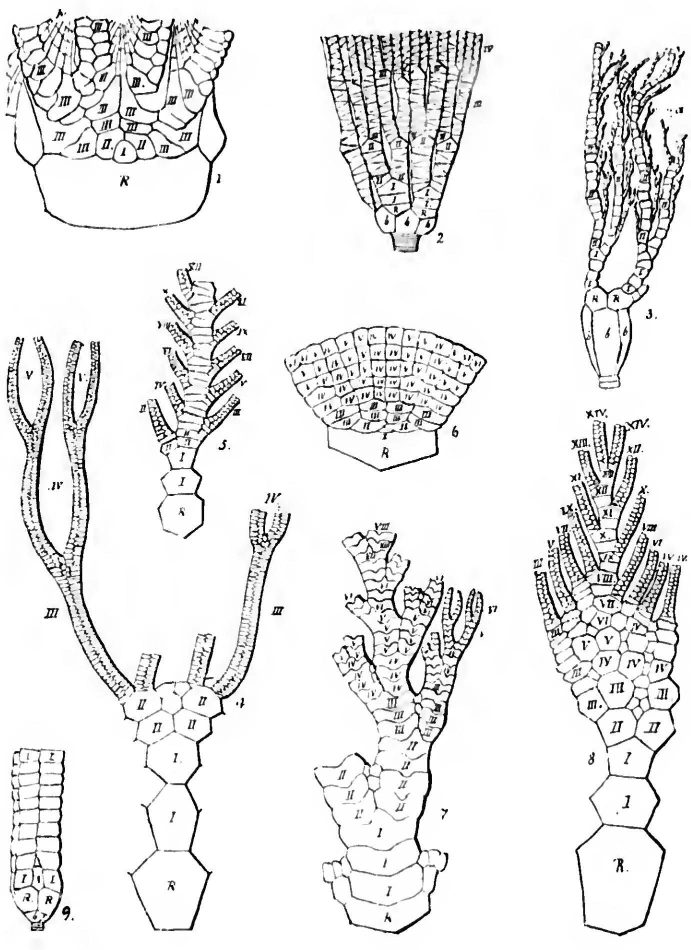
## EXPLANATION OF TABLE B.

### THE PLATES OF THE RAYS IN DIFFERENT GENERA.

1. Part of ray of *Marsupiocrinus;* costals, distichals, first and second palmars — of the latter only those of the two outer sides of the rays — abutting against the radials.
2. *Scaphiocrinus.* Arms uniserial; pinnulated; dichotomizing; the joints cuneate.
3. *Belemnocrinus typus.* Arms uniserial, giving off armlets at intervals.
4. A ray of *Periechocrinus Whitfieldi.* Arms biserial, branching in the free state.
5. Proximal part of a ray of *Steganocrinus sculptus.* Arms biserial, given off alternately from opposite sides of tubular appendages.
6. Proximal part of a ray of *Crotalocrinus pulcher;* the lower brachials arranged as in Fig. 1.
7. Part of ray of *Onychocrinus ramulosus.* Arms uniserial; the main branches giving off branchlets in clusters.
8. [illegible] section of a ray of *Strotocrinus regalis.* The arms given off from the proximal plate at alternate sides within the calyx.
9. *Symbathocrinus Wachsmuthi.* Arms uniserial, composed exclusively of costals; the joints arranged parallel.

The following symbols are used in the figures: R = radials; I = primary brachials or costals; II = secondary brachials or distichals; III = tertiary brachials or palmars; IV = fourth order of brachials; V = fifth order of brachials; and so on; p. = pinnules; a. = armlets.

## TABLE B.



The above terms which were accepted by Mr. Bather in 1890,* and used in his earlier papers "On the British Fossil Crinoids, were in January, 1892 † abandoned by him and substituted by others. He stated that he found certain difficulties in their application to Palæozoic forms, and proposed in place of them the following terms: —

| | | | |
|---|---|---|---|
| Primibrachs | = | our primary brachials, or Costals. | |
| First primibrach | = | " first costal. | |
| Second primibrach | = | " second costal. | |
| Primaxil | = | " axillary costal. | |
| Secundibrachs | = | " secondary brachials, or Distichals. | |
| Secundaxil | = | " axillary distichal. | |
| Tertiobrachs | = | " tertiary brachials, or Palmars. | |
| Quartibrachs | = | " brachials of the fourth order | Postpalmars. |
| Quintibrachs | = | " brachials of the fifth order | |
| Sextibrachs | = | " brachials of the sixth order | |
| Etc. | | Etc. | |

This nomenclature is based upon the same principle as our own, and even the names are not so very different considering that the terms "costals," "distichals," and "palmars" are proposed as equivalents of "primary, secondary, and tertiary brachials;" but Bather proposed these terms for the pinnuleless forms only, and brought out another terminology to be applied to pinnule-bearing arms, viz.: —

Monostichals (First Order).
First monostichal.
Second monostichal.
Monaxil (First Mainaxil).
Distichals (Second Order).
Distaxil (Second Mainaxil).
Tetrastichals (Third Order).
Tetraxil (Third Mainaxil).
Octastichals (Fourth Order).
(Fifth Order).
(Sixth Order).

That the branching of pinnuliferous arms, as supposed by Bather, is almost quite regular, is by no means the case. We frequently find among Camerate Crinoids rays with three, five, six, seven, nine, and ten arms, instead of two, four, or eight. In *Strotocrinus*, there are rays with thirty arms in the calyx, and the "Finials," which here comprise the plates of the free arms, although given off from the *fourteenth* axillary, are "Triacontastichals." Still more complicated is the case in *Steganocrinus*, *Eucladocrinus*, *Ripidocrinus*, and *Melocrinus*, in which, to the full length of their rays, from the costals or distichals up, the brachials are developed into rigid

* Ann. and Mag. Vol. V. p. 313.

† Ibid., Vol. IX. pp. 51-61.

calycine tubes, and the original pinnules into alternately arranged pinnule-bearing arms. This shows that the second part of Bather's terminology cannot be carried out practically, and we see no good reason why the former terms could not be used for all Crinoids, pinnulate or non-pinnulate.

The costals of the Camerata, as a rule, consist of two plates to the ray; exceptionally of one or three. *Platycrinus* has generally but one; but two of its earlier species have two, and it is quite probable that the genus originally had two costals, which later on were united into one. This seems to be confirmed by the fact that some of the species have transverse grooves at the dorsal face of the plates, and that in multibrachiate species, the distichals and succeeding orders are composed of two pieces. *Stereocrinus* also has but one costal, which has the proportions of the combined first and second plates of *Dolatocrinus*, with which it has very close affinities. The same structure is found in *Anthemocrinus* and *Hadrocrinus*. *Dichocrinus* has two costals, which form a syzygy, the epizygal supporting an arm. The allied *Talarocrinus* and *Pterotocrinus*, however, have but one. In *Batocrinus*, and in most of the Batocrinites, the first costal is very short, and is frequently anchylosed with the second in one or more of the rays. Three costals occur among Camerate Crinoids only in *Reteocrinus stellaris*, and in Hall's imperfectly known *Schizocrinus*.

Among the Articulata the number of costals is more variable, and often differs among the rays of the same individual. *Forbesiocrinus Agassizi** may have two or three costals in all its rays, or four only in one or two of them. *Calpiocrinus* and *Mespilocrinus* have two, *Ichthyocrinus* and *Taxocrinus* two to three, and *Anisocrinus* but one; while *Onychocrinus* has from three to six.

The number of costals is still more variable in certain groups of the Fistulata, in some of which such irregularity is the rule. This is the case in *Cyathocrinus* and *Parisocrinus*, in which one ray may have two, the adjoining one three, and the next perhaps five or six. *Codiacrinus* has two to three, *Atelestocrinus* from two to six. Less variable among the rays, but still numer-

* We are of the opinion that *Forbesiocrinus nobilis*, de Koninck's type of the genus, is generically identical with *Onychocrinus* Lyon. We recently obtained from Tournai, Belgium, a fine specimen with arms, which clearly shows that it has a small anal tube resting upon the first anal plate. The rays are free above the first costal, and are extremely heavy to the fourth distichal, whence they branch off into numerous small, curving armlets, exactly as in *Onychocrinus exsculptus* Lyon. De Koninck stated that in his species the plates of the anal side, which were imperfectly shown in the specimens, were probably more numerous than those of the other sides, whereas the fact is the opposite; and this statement, no doubt, led Hall and others to refer *Forbesiocrinus Agassizi* and allied forms, in which that actually is the case, to de Koninck's genus. If, therefore, de Koninck's type is that of *Onychocrinus*, the latter name may have to be abandoned, and a new generic name proposed for such forms as *F. Agassizi*.

ous, are the costals of *Dendrocrinus* and *Homocrinus*, in which we have counted as many as seven; *Iocrinus* has four, *Anomalocrinus* from two to four in the same species. Most of the other Fistulata have one or two. When there is but one plate, it is generally twice as long as the two, the latter forming a syzygy. We find this in the majority of the Poteriocrinidæ, except in the anterior ray, which in some species has as many as twelve costals, while in others it has no bifurcation at all, and the arm is composed of costals only. A few of their species have from five to eight costals in each ray, and *Poteriocrinus missouriensis* from ten to fourteen. In the Hybocrinidæ, and in the Larviformia as a rule, the arms are formed exclusively of costals (Fig. 1); and only occasionally in *Allagecrinus*, in one or two of its rays, the radials are axillary and in the absence of costals support two rows of distichals.

From these facts it is obvious that the number of costals does not constitute a reliable character for classification, as heretofore supposed, and that in some groups their number is of but little value for specific distinction. This is even more markedly the case with regard to the higher divisions of the rays.

The distichals are borne upon the axillary costal, which splits the ray into two divisions, and all succeeding bifurcations take place from one or both of these divisions. To this rule, however, there are a few exceptions: *Steganocrinus sculptus*, a few species of *Melocrinus*, *Hypocrinus* and *Calamocrinus*, have no regular distichy, and all their branches are given off from one trunk. A similar structure is found among the Poteriocrinidæ in the posterior ray. In most of their species with two arms to the ray the posterior ray has but one trunk, and in multibrachiate forms the first bifurcation of the posterior ray corresponds with the second in the other rays. Branching takes place either alternately from opposite sides, or by means of dichotomy. The former is very frequently the case among the Camerata, and is the rule in the Actinocrinidæ.

The arms are composed of one or two rows of plates. The uniserial arms are composed of either rectangular or cuneate plates, the former being the most archaic form. The cuneate plates are alternately arranged, and gradually pass into a biserial arrangement. Arms are called "biserial" when the plates interlock, and do not reach to the full width of the arm. This explains why in biserial arms the pinnules are given off from every plate at each side of the arm, while in uniserial arms every second plate at each side bears a pinnule.

That the biserial arms represent the higher form is clearly shown by their mode of growth, and their gradual introduction in geological time. In the young dicyclic Crinoid, as we had occasion to observe especially well in the genus *Platycrinus* (Plate LXXIII. Fig. 10, and Plate LXXV. Fig. 11), the arms are uniserial throughout, their outlines waving, the plates decidedly wedge-shaped, the pinnules proportionally large and given off alternately as in true uniserial arms. In somewhat older specimens, the plates at the tips gradually interlock, and the new ones still forming at the distal end are strictly biserial. With advancing maturity the interlocking gradually extends to the proximal ends, until finally in the adult *Platycrinus* the whole arm becomes biserial, except perhaps as to a few plates near the calyx, which permanently retain their larval condition. Similar modifications occurred in geological time. In the Lower Silurian the arms of monocyclic Camerata are uniserial, almost without exception. In the Niagara group and Wenlock limestone, however, they rapidly change into biserial. It is very significant that among the species of that epoch we find as persistent characters all the phases through which the arms of the individual Crinoid pass in early life. This is well shown in the case of the Batocrinidæ.* The arms of *Habrocrinus* and *Dimerocrinus* are uniserial; but while the plates of the former are always rectangular, those of the latter in some species are decidedly cuneate. The same modifications can be observed among the arms of *Patelliocrinus* and *Stelidiocrinus*, but in some of their species the cuneate plates already begin to turn into biserial by interlocking. We thus find in the same genus, and almost contemporaneously, all the variations from uniserial arms to biserial; and, what is most significant, the arms of all Devonian and later Batocrinidæ are strictly biserial. Turning to the Platycrinidæ, we find that the Upper Silurian *Cordylocrinus* has uniserial arms, formed of rectangular or cuneate joints, while in *Marsupiocrinus*, *Culicocrinus*, and *Platycrinus* they are biserial. We may note also the case of the Hexacrinidæ, in which the development of the arms took place at a later period. The arms of the Devonian genus *Hexacrinus* are uniserial, and also those of the earlier species of *Dichocrinus*. The plates of the latter are rectangular in all Kinderhook species, and also in about half of those from the Burlington and Keokuk groups; in most of the others they are wedge-shaped, and in a few of them the arms fairly enter the interlocking stage. All species, however, of the Kaskaskia group have biserial arms, and likewise the contemporaneous *Talarocrinus* and *Pterotocrinus*. Among the Melocrinidæ, *Glyptocrinus* and

* We have separated the Batocrinidæ from the Actinocrinidæ, referring to them only those genera in which the anal plate is followed by three interbrachial pieces, instead of two as in the latter family.

*Compsocrinus*, — both from the Lower Silurian, — have uniserial arms; *Periglyptocrinus*, and probably all later Melocrinidæ, biserial. Among dicyclic Camerata, we find well defined biserial arms already in the Trenton and Hudson River groups, along with uniserial, the former being perhaps in the majority; but the latter are continued to the lower part of the Devonian by two species,* and these, together with the species of *Dichocrinus*, are, so far as we know, the only representatives of the Camerata with a single row of arm plates that survived the close of the Silurian.

In the Fistulata, the biserial arm structure was introduced just before the close of the Carboniferous, but only in a limited way. True biserial arms only occur in *Graphiocrinus*,† *Eupachycrinus*, *Cromyocrinus*, *Hydreionocrinus*, *Erisocrinus*, *Stemmatocrinus*, and *Encrinus*, but the majority of species have either quadrangular or cuneate arm plates, and in some of them only the tips of the arms begin to interlock. In this group the biserial stage at no time became a constant character, not even in the Triassic. *Encrinus liliiformis* has perfectly biserial arms, while the arms of *Encrinus gracilis* are uniserial, and composed of quadrangular plates.

The arms of the Articulata, not only in Palæozoic pinnuleless forms, but also in the Neozoic pinnule-bearing ones, are uniserial without exception.

The pinnules, as happily expressed by Carpenter, are repetitions of the arms on a small scale; and in their organization morphologically, and to a large extent physiologically, closely resemble ordinary arm branches. They are short branchlets given off along the sides of the arms, but rarely reaching their tips, and are usually more slender, and composed of longer joints. The pinnules differ from arms in containing the fertile portions of the genital glands, while the arms lodge the genital cords. Like the arms, they have ambulacral furrows fringed with cilia, by means of which particles of food coming in contact with them are carried along the grooves to the

* Oehlert's new genus *Diamenocrinus*, and "*Rhodocrinus*" *gonatodes* Müller (both from the lower Devonian), which perhaps belong to one genus, have dichotomizing arms, composed of short, quadrangular plates.

† It is doubtful if the name *Graphiocrinus* can be retained, according to the general rules adopted by naturalists, as it was incorrectly defined by de Koninck and Le Hon. The type has small infrabasals hidden by the column, and the position of the anal plate is materially different from that given by the Belgian writers, which probably was not known to Trautschold when he proposed the genus *Phialocrinus*. The anal plate of *Graphiocrinus encrinoides*, de Koninck's type, rests directly upon the truncated posterior basal, as we observed in a fine specimen in our collection, exactly as in *Phialocrinus*. There is, however, a slight objection to Trautschold's name, which was preoccupied by Eichwald (Lethæa Rossica I, p. 578), but the genus was founded merely upon fragments of column. That *Phialocrinus patens* has two costals, and *Graphiocrinus encrinoides* but one, may not be of generic importance, as the two plates of the former are equal to the one of the latter, which evidently form a syzygy.

mouth. In their normal condition the pinnules are arranged alternately on opposite sides from every second joint, so that each joint bears a pinnule. When the interval between the pinnules is greater, which is frequently the case at certain parts of the arms, especially among recent Crinoids, this has been called a syzygy. The term was applied by Johannes Müller * to the immovable union of two arm joints, of which only the upper one is pinnule-bearing. The two plates, to which the names "hypozygal" and "epizygal" were given, — the later for the pinnule-bearing one, — count in the alternation of the pinnules as one joint. Their apposed faces are not necessarily striated, as indicated by Müller, being sometimes dotted or smooth. Smooth syzygial faces have been observed in recent Crinoids only in a few Comatulæ, but they occur quite frequently among Palæozoic species. In the latter, we also find occasionally a succession of two or three hypozygal joints in the same syzygy.†

Syzygies do not occur among Palæozoic Crinoids at irregular intervals as in recent ones. Either they have a continuous series of syzygies throughout the whole arm, as in the Heterocrinidæ and a few genera of the Camerata, or there is one syzygy in each order of brachials, which is formed by the two proximal plates. The latter is frequently the case among the Poteriocrinidæ, Encrinidæ, and also in the Camerate genus *Dichocrinus*. In *Dichocrinus*, the suture between the syzygial plates is very close, and the line of union more faint than the lines of adjoining plates. In the Poteriocrinidæ either the apposed surfaces are flat, or the hypozygal plate is slightly excavated, and the epizygal correspondingly convex. In *Encrinus liliiformis* the corresponding faces are dotted so as to make a very close union. The Poteriocrinidæ may have one or two costals within the same genus. In species with two, both plates together take the form and size of the one; and this rule applies to the proximal distichals as well. That the two plates of the costals, as well as those of the distichals, form a syzygy, is practically shown by the pinnules, which in species with but one costal begin with the first plate after

* Ueber den Bau des Pentacrinus caput medusæ (Abhandl. d. K. Akademie der Wissenschaften, Berlin, 1843, p. 215).

† The term "syzygy" has also been used by some writers for the immovable union of the nodal stem-joints with those next below them, as in the case of *Pentacrinus*. This, we think, is not in accordance with Müller's definition, who proposed the term for two arm-joints of which only the upper is pinnule-bearing, and not for a special mode of union between plates generally. Radiated and dotted surfaces do not always imply a syzygy. Such faces are found among Palæozoic Crinoids very frequently on the ordinary arm plates, and even, as in *Crotalocrinus*, between the plates of the dorsal cup. The union between the syzygial joints is nothing but an ordinary close suture, which may have striated or smooth surfaces.

the axillary; while in species with two costals the first pinnule is given off from the second distichal. In the Heterocrinidæ, in which the syzygies prevail throughout the whole arm, they are formed in most of the species by more than two plates. While *Epactocrinus grandis* has but one hypozygal, *Heterocrinus* has two or more, followed by the epizygal bearing the pinnule, which in this group might be properly called an armlet. A similar arm structure is found among the later Calceocrinidæ, and also in the Belemnocrinidæ. In *Epactocrinus grandis* the syzygies are especially well marked, the epizygal joints being wedged-shaped, the hypozygal quadrangular, and arranged parallel to the distal faces of the preceding epizygal.

In some groups of the Fistulata it is exceedingly difficult to discriminate between pinnules and armlets. As a rule, pinnules are more delicate, and are given off, except in cases of syzygy, from successive joints; while most of the armlets are arranged at more or less irregular intervals along the sides of the ordinary arms, and are usually branching. We find armlets among the Heterocrinidæ, Belemnocrinidæ, in *Barycrinus*, *Botryocrinus*, and the later Calceocrinidæ. The Cyathocrinidæ have long filiform arms, which frequently dichotomize, but have neither armlets nor pinnules. The Anomalocrinidæ have branching arms with pinnules. The latter are given off in rows from every joint at one side of the arm only — not alternately from opposite sides — from one axillary to another, reversing their position in the successive divisions. The Hybocrinidæ, which represent one of the most primitive forms of the Fistulata, possess but one arm to the ray, and have neither pinnules nor armlets. The Catillocrinidæ have numerous simple, pinnuleless arms, given off directly from the radials, without the interposition of axillaries.

In the Camerata the lower brachials take part in the calyx. That these plates were free in the early larva, and were gradually incorporated, is clearly indicated by the ontogeny of recent Crinoids, as well as the phylogeny of fossil ones. In the early Pentacrinoid larva of *Antedon* the arms are free from the radials up, and the costals and distichals are subsequently drawn into the calyx by the gradually increasing perisome. This was evidently the case in the Camerata also. But while in the former the perisome consists of soft tissues encrusted with limestone particles, the perisome of the latter is formed of well-defined plates. Our knowledge of the ontogeny of Camerate Crinoids is of course limited; all we know is that smaller specimens have a less number of interbrachial plates, that the number increases with the size of the specimens, and that with the increase of the latter additional brachials are incorporated into the calyx. We have found a number of young specimens in which the arms are free from the first axillary, but, as yet, no *Actinocrinus* or *Rhodocrinus* in which there is not at least one interbrachial.

We find among the Camerata a large number of transition forms in which the costals do not form a part of the dorsal cup, and the first inter radials, to a large extent, are interambulacral in position. Such is the case in the Platycrinidæ, Hexacrinidæ, Acrocrinidæ, and Crotalocrinidæ. In *Platycrinus* the distal ends of the radials are provided with a horse-shoe-shaped excavation, which closely resembles the facets of the Inadunate Cyathocrinidæ. This facet, which in some species extends down to two-thirds the length of the plate, rarely takes up more than half its width. It is occupied by the costals, or, when these are very small, in part also by the first distichals. The costals are narrow, and resemble in form and general appearance the free brachials of Inadunate Crinoids. They are, however, not free in the sense of these, but the proximal ends of one or both plates are suturally connected with the plates of the tegmen, so as to be immovable, and only their upper ends are free from the calyx.

It has been generally supposed that there was in *Platycrinus* and *Dichocrinus* an articulation or loose union between the radials and costals. This seemed to be confirmed by the presence of the facet, and by the fact that in some species this is provided with a sort of imperforate transverse ridge, or angularity. We have no doubt that these costals were movable at some period of life, probably in the larva before the perisome made its appearance, and the orals still rested upon the beveled edges at the outer ends of the radials. But it is equally certain that the plates were immovable in the adult, owing to the rigidity of the interradial and covering pieces, with which they are suturally connected. The systematic position of the Platycrinidæ is intermediate between the Inadunata and the typical Camerata. They represent phylogenetically an early stage of *Actinocrinus*, *Batocrinus*, and their congeners; but are nevertheless true Camerate Crinoids, for their lower brachials are fixed, retaining, however, permanently to a large degree the characteristics of free arm plates. In *Culicocrinus* and *Pterotocrinus*, the one a Platycrinoid, the other a Hexacrinoid, the Camerate type is somewhat more advanced, as their costals practically enter the dorsal cup; and there are a few species of *Platycrinus* in the same condition (Plate LXXI., Fig. 16).

So there is an almost uninterrupted series of forms from the Inadunata to the most completely developed Camerata.

It has been stated that in *Dichocrinus* the various orders of brachials, to the last bifurcation, consist of two plates each, and that the plates of each order form a syzygy, the epizygal bearing an arm instead of a pinnule. A similar structure is found in most species of *Platycrinus* from the costals up, and although the union between these plates may have been less close than in *Dichocrinus*, they evidently form a syzygy, except in cases in which the first plate of the order is pinnule-bearing, as in *P. Huntsvillæ* and *P. Saræ*. It is very significant that in both these species, and a few others, the first pinnule is given off from the first distichal, and the second on the same side from the first palmar, thus showing that the arm partakes of the alternation of the pinnules; and this suggests the question whether all arm-branches are not enlarged pinnules. In *Eucladocrinus*, which is actually a highly differentiated *Platycrinus*, the branches are given off alternately from every second joint up to the end of the rays, exactly like the pinnules in cases of syzygy; but while in *Platycrinus* the axillaries are in their normal condition,—the superior faces equally divided,—in *Eucladocrinus* they are of irregular form. They resemble enlarged pinnule-bearing plates, of which the side supporting the next order of brachials is much wider than that giving off the arm (Plate LXXIV).

There can be but little doubt that in *Eucladocrinus* the lateral arms in the young Crinoid were pinnules; and there is abundant proof that this was also the case with the arms of other groups, as is well shown by *Glyptocrinus Dyeri*. In most species of *Glyptocrinus*, for example, *G. decadactylus*,* the second bifurcation takes place from the second distichal. In *G. Dyeri*, however, this plate gives off from one side in place of an arm a large pinnule, more than twice the size of an ordinary one; and a second pinnule, but little smaller, starts off from the fourth distichal on the opposite side. Both pinnule-bearing joints have nearly the shape of true axillaries, and what is most remarkable, the arm bends outward, forming an angle, as if a true bifurcation took place. (Plate XX., Fig. 1 *a*, *b*, *c*). The four or five proximal pinnules of this species are incorporated into the calyx, and it is quite evident that the growth of the armlets — or pinnules, whichever they are — was arrested by the rapid upward growth of the perisome. All succeeding pinnules are small, and given off alternately from successive joints.

* This species has twenty arms, and not ten as indicated by the name.

The structure of this species is a very strong indication that the arm branches are modified pinnules; and this suggests that non-pinnule-bearing brachials, whether fixed or free, may form a syzygy whether the succeeding axillary supports an arm or a pinnule. Carpenter pointed out * that among recent Crinoids, with but few exceptions, "the first two joints beyond every axillary of the dividing rays are united to one another in the same manner, either by syzygy or bifascial articulation." This rule seems to hold good also for most of the Palæozoic Crinoids, with the exception that we find among them only syzygies, and no articulation.

The Actinocrinidæ, as we have stated, represent an advanced stage of the Camerate type. Not only their costals, but also their distichals, and generally several more orders of brachials, participate in the formation of the calyx, and all the branches are given off alternately from opposite sides of the main trunks. In the genus *Actinocrinus*, † only every second or third brachial of each order in the calyx supports an arm (Plate LX., Fig. 1*a*); but in *Cactocrinus*, *Physetocrinus*, *Teleiocrinus*, and *Strotocrinus*, an arm originates from each successive plate (Plate LXV., Figs. 1*a* and 1*c*), and the arms alternate like the pinnules. In *Actinocrinus* occasionally, and in *Amphoracrinus* generally, branches are also given off at irregular intervals from the free arms; but these evidently made their appearance after the arms had become biserial. In *Steganocrinus* the branching is continued to the top of the rays, as in *Eucladocrinus* (Plate LXI., Figs. 1*a* and 1*d*), and each order of brachials consists of one, two or three plates, which are formed into tubular appendages of the calyx, giving off biserial, pinnule-bearing arms. According to our interpretation, we have in *Actinocrinus* and *Steganocrinus* a series of syzygies, in the former extending to the top of the calyx, in the latter to the top of the rays; as opposed to *Cactocrinus*, *Strotocrinus*, etc., in which each order of brachials consists of a single plate, which is axillary.

The pinnules of the Actinocrinidæ differ from those of other families in being provided with prominent hooks, directed obliquely upward and outward. These hooks are arranged in rows parallel to the sides of the arms, and those of one pinnule overlap the corresponding ones of adjoining pinnules (Plate LVIII., Figs. 1 and 7*a*, *b*, *c*), so as to give to the mass of pinnules the appearance of a highly complicated network.

* Chall. Rep. I., p. 49.

† We subdivide the genus *Actinocrinus*, as heretofore recognized, into *Actinocrinus proper*, and *Cactocrinus*; referring to the former only the lobed species with two or more brachials to each order; and to the latter those in which the free arms are arranged equidistant around the calyx, and each order of brachials above the costals consists of but one plate.

In the Batocrinidæ, we find an arm structure such as occurs in no other group. While in all other Camerata the ambulacral openings of the calyx give origin to but a single arm, those of the Batocrinites frequently bear two, either from every opening or from any less number of them, and this, which is very remarkable, even in the same species. Thus the specimens may have eighteen arm openings and but eighteen arms, or any number from eighteen to thirty-six. This mode of multiplying the number of arms is found only among the later forms, and it is evident from the structure that the second arm, where it occurs, was introduced in the nearly mature individual after the arms became biserial, and the lower orders of brachials had been incorporated into the calyx. The bifurcation takes place in the same manner as in free biserial arms, there being no true axillary, and the plate taking its place is no larger than the succeeding arm pieces.

In the Batocrinidæ, all branching in the calyx is by means of dichotomy, and the number of arm openings in the three anterior rays rarely exceeds four; but there may be only two or three, and in the posterior rays, the arms next to the anal interradius may bifurcate once or twice again, so that two of the rays have five or six arm openings. In some genera the number of arm openings varies considerably among the rays, the anterior, or occasionally the antero-lateral ones, being generally the least developed. This is not the case in the Actinocrinidæ, in which normally, with one or two exceptions, the number of arms is equally divided among the rays. In the Periechocrinites, which we made a subdivision of the Batocrinidæ, the free arms almost always branch in their biserial stage ; while they remain simple in the Batocrinites.

In *Melocrinus* a very peculiar arm structure occurs, somewhat similar to that of *Steganocrinus* and *Eucladocrinus;* but while in the latter the two divisions of the ray form independent appendages, all the way from the calyx up, those of *Melocrinus*, either for some distance or to the full length of the rays, are laterally connected, and form together but one appendage, from which the arms are given off at intervals from opposite plates in the ray, and from one side only of each half.

In most of the Rhodocrinidæ and Thysanocrinidæ, the arms branch in their free stage, whether uniserial or biserial. The arms of *Ripidocrinus* are given off at both sides of the main rays, as in *Steganocrinus sculptus*. Those of *Gilbertsocrinus* are very delicate, and frequently pendent. The latter is the case also in some species of *Acrocrinus*, and the Swedish genus *Barrandeo-*

*crinus*, in which they completely envelop the calyx, exposing their ventral surfaces.

The mobility of the arms in the Camerata must have been limited, as we nowhere find at the apposed faces of the various brachials any trace of a muscular attachment. Those brachials which take part in the calyx are, like the other calyx plates, united with one another and with adjoining plates by close suture, the apposed surfaces being flat and generally smooth, rarely striated; and the plates are immovable. The first indication of any kind of articular facet occurs on the highest plate of the calyx; *i. e.*, that bearing the free arms. This plate is usually more or less concave, often striated, sometimes having a sort of ball-and-socket arrangement, or being provided with an obscure transverse ridge; and in a few cases it is perforated. The faces of the higher arm plates are smooth or striated, and but little concave; yet there must have been a considerable amount of mobility even among them, for the tips of the arms are frequently curved inward, and in some cases the arms are decidedly spreading.

The mode of union between the brachials of the earlier Fistulata was similar to that of the Platycrinidæ. The Dendrocrinidæ and Cyathocrinidæ have more or less well developed facets upon the radials, and the arm plates are united among themselves and with the radials by ligaments only, so as to admit but little motion. In the later Fistulata, however, notably the Poteriocrinidæ * and Encrinidæ, there is a muscular articulation between the axillaries and the joint succeeding them, as in recent Crinoids.

The Larviformia, so far as they are known, have a well differentiated muscular articulation, with transverse ridge and fossæ between the radials and costals, but not between the succeeding brachials. *Cupressocrinus*, *Allagecrinus*, and *Symbathocrinus* have large muscle plates connected with the radials; while the other brachials are so closely united one to another that it appears as if the whole arm had moved rigidly upon the radials.

In the Ichthyocrinidæ all the brachials, whether fixed or free, are movable. The calyx was pliable from the radials up, as is shown by the apposed faces of the plates, which are deeply hollowed out; not only those of the brachials, but the interbrachial plates as well. The cavities, which evidently lodged large bundles of ligament, contain small elevations with stri-

* It is unfortunate that the genus *Poteriocrinus* has been made the type of this family. It is the only genus of the Poteriocrinidæ in which the facet supporting the arms is horse-shoe-shaped, and the costals do not occupy the full width of the radials, which is so characteristic of the family.

ated faces. Those of the fixed brachials form irregular ridges, which proceed from both sides of the plates toward the middle without meeting. The apposed faces of the free arm plates have been rarely observed, but so far as known they are more or less concave, and we have found on some of them indications of transverse ridges. The lines of union between the brachials generally have a waving outline, and many of the species have a sharp process projecting from the distal end of the plates, which fits into a shallow depression upon the outer face of the plate below. In some species, especially the larger ones, this projection forms a separate plate. The arms of all Ichthyocrinidæ are uniserial, the joints quadrangular, and they are destitute of pinnules.

## II. THE PLATES OF THE ACTINAL SYSTEM.

### A. *The Orals.*

The orals are not always represented in the adult Crinoid. When present, they surround the mouth or cover it; and they may occupy the whole face of the ventral disk, or only its median portions. In the former case they rest upon the edges of the radials; in the latter against the perisome. In Crinoids with a regular pentamerous symmetry they consist of five pieces, interradially disposed, and occupy the centre of the disk. When the symmetry is irregular, they are pushed more or less toward the anterior side. The former condition prevails among the recent Crinoids, and in the Larviformia; the latter is the general rule among Palæozoic forms. When asymmetrical, the posterior oral is pushed in between the four others, and is generally larger (Plate III., Figs. 11, 17, 18, 20, 21, 22, and 23).

The orals are among the earliest plates developed in the larva. They make their appearance simultaneously with the basals, upon which they rest until the radials are introduced, when they occupy the beveled upper edges of the latter plates. In the larva of recent Crinoids they form a pyramid, composed of five nearly equal pieces, which at first are laterally united and closed at the top; but they soon open out, and expose the tentacular vestibule. At a more advanced stage the orals are carried inward by perisome, until finally in most of the species they become resorbed, and are replaced by upward perisomic growth. In only a comparatively few recent forms do they persist through life, and in these cases they occupy the median portions of the disk, and enclose the oral opening (Plate III., Figs. 9 and 10).

While thus among recent Crinoids the orals are readily recognized, their identification among Palæozoic forms has been the subject of much controversy. Allman * in 1863 expressed the opinion that the group of plates in the centre of the vault of many Palæocrinoids is a representative of the simple oral system of the young *Comatula;* but as those plates often consist of more than five, it was not made clear to which particular ones his homology applied. In most Palæozoic Crinoids there is no oral opening, and the arrangement of the plates at the summit is irregular and quite variable. This is the case particularly among the Camerata, in which the median portions of the disk are generally occupied by a large, centrally located plate, surrounded by eight or nine others, of which four are large and similar in form and size. These four larger plates are directed toward the anterior side of the disk, forming at their outer edges re-entering angles, which are filled by three rather large plates, radially disposed; while the four or five smaller plates of the proximal ring are directed posteriorly, and are followed by numerous more or less irregular pieces, directly or indirectly connected with the anus (Plate III., Figs. 17, 18, 20, 21, 22, and 23). Occasionally the larger plates are separated from one another by small, supplementary pieces (Plate III., Fig. 23). This is the case in some of the larger species, in which the small pieces were introduced in the growing Crinoid. There are also species in which the larger plates are not represented at all, and the whole ventral disk is composed of minute pieces without definite arrangement, leaving only an opening for the anus (Plate III., Fig. 24).

The interpretation of these plates has proved the more difficult because in other groups, notably the Larviformia, the tegmen consists of but few pieces, which have a different arrangement. In *Allagecrinus* and *Myrtillocrinus* (Plate III., Fig. 13), the whole ventral surface is covered by five large interradial plates, resting upon the superior edges of the radials, exactly as the orals in the Pentacrinoid larva of *Antedon. Haplocrinus* (Plate III., Fig. 14) has five similar plates, which were at one time supposed to surround a small central plate.† *Symbathocrinus* (Plate III., Fig. 25) has a pyramid of five large plates, four of them resting upon the edges of the muscle plates of the radials, and partially surrounding a larger one, wedged in from the pos-

* Trans. Roy. Soc. Edinb. Vol. XXIII., pp. 245–251.

† Our supposed discovery of this plate in a specimen of *Haplocrinus mespiliformis* proved afterwards to be a mistake, due to the peculiar fractures in the specimen. Carpenter, to whom we submitted the specimen,

terior side to a nearly central position. The description of the ventral plates of this genus in the Revision, Part III., p. 87, was incorrect as to the small pieces around the five summit plates, the appearance of which was produced by cracks and not sutures. Specimens of better preservation show positively that the ventral surface is occupied exclusively by the five large plates. *Pisocrinus*, as shown by a specimen of *P. pilula* in our possession from Dudley, England, has a similar structure. Among the Camerata five large summit plates are known to exist only in *Coccocrinus* and *Culicocrinus*, the plates of the former being equal (Plate III., Fig. 14), those of the latter slightly unequal.

As the large central plate, when it occurs, occupies approximately the same position as the oral opening of recent Crinoids, it seemed plausible that the orals, if present at all, should be looked for in the Camerata among the plates of the proximal ring; but on examining the structure, it was found that only the four larger plates could be compared with the five orals of recent forms; so the question arose, what had become of the corresponding fifth plate?

Wachsmuth, in 1877,* directed attention to the two plates of the same ring adjoining the four larger ones, and suggested that these two plates taken together were probably equivalent to one, being split into two by the anus, and that the six plates represented morphologically but five. The plates were not, however, regarded by him as the orals; he thought the whole ventral covering of the earlier Crinoids was structurally distinct from the disk of recent ones.

A similar view of the subject was taken by us in the following year.† We assumed that the plates of the dorsal cup and those of the tegmen were parallel structures; that the central plate was represented in the dorsal cup or abactinal side by the infrabasals, the six proximals by the basals, and that other plates of the tegmen represented the radials and interradials. No comparison was then made by us of these plates with the plates in the disk of recent forms; but this was done in 1881,‡ when we suggested that the six proximals represented the orals.

Dr. P. H. Carpenter, like ourselves, recognized in the Camerata a central plate, for which he proposed the name "oro-central," and six proximals

verified our observation, and held the plate to be homologous with the so-called central plate of the Camerata. (Chall. Rep. on the Stalked Crinoids, p. 158).

* Amer. Journ. Sci. and Arts (series 3), Vol. XIX. pp. 186-187.

† Revision, Part I., p. 28.

‡ Revision, Part II. p. 17 (Proceed. Acad. Nat. Sci. Phila., p. 191).

surrounding it. He regarded the former as the actinal representative of the dorso-central or terminal plate of the stem, and the latter the representatives of the basals. He took the proximals to be the orals, believing with us that the posterior oral was divided into two plates. He said:* "The proximal dome plates rest directly against the calyx interradials, that on the posterior side being represented by two small plates with the anus between them; while there is a more or less tubercular ring of radial dome plates outside them. These proximal dome plates thus correspond exactly to the orals of *Symbathocrinus* and *Haplocrinus*, covering in the peristome, and resting against the calyx plates, which in *Platycrinus* are the interradials, and not the upper edges of the radials, as in the simpler forms. . . . I cannot see what other view can be taken of the proximal dome plates which immediately surround the oro-central, than to regard them as orals; *i. e.*, as the actinal representatives of the basals, like the corresponding plates in *Symbathocrinus*. If this be admitted, it follows that the proximal dome plates of all Platycrinidæ, Actinocrinidæ and Rhodocrinidæ are also homologous with the orals of Neocrinoids." † Carpenter's oral theory was based almost entirely upon the hypothetical oro-central, — a plate before unknown in Echinoderm morphology, — and the six proximal plates, which he assumed to be orals, although their morphological relations had never been established.

The same view of the question was also taken by Etheridge and Carpenter,‡ and afterwards by Neumayr;§ while Zittel ‖ supposed the orals to be unrepresented in all Platycrinidæ, Actinocrinidæ, Rhodocrinidæ, and Calyptocrinidæ; though admitting their presence in some of the other groups.

The above theory was laid aside by us in 1885, when we ascertained that the two smaller proximals, which we had supposed to represent the posterior oral, occupy a radial position, and therefore could not be orals. The structure shows that these plates undoubtedly represent the two posterior radial dome plates, pushed to a position among the plates of the proximal ring by the anus, the three anterior ones retaining their position within the re-entering angles of the four larger proximals. This discovery was announced by us in Part III of the Revision, p. 47, and we designated the respective

* Chall. Rep. Stalk. Crin., pp. 170 to 171.

† Dr. Carpenter's views on this subject are fully set forth in the Chall. Rep. Stalk. Crin., pp. 158 to 184.

‡ 1886. Catalogue of the Blastoidea, pp. 66 to 75.

§ 1889. Die Stämme des Thierreiches, p. 448.

‖ Handb. der Palæont., I, p. 332.

plates by the letters "*rx*" in the accompanying diagrams.* There now remained among the plates of the proximal ring but four which could possibly be taken for the orals; and this led us to inquire whether the central plate alone might not be a coalesced representative of the five orals of recent forms.

From internal casts we observed that this plate occupies the centre of radiation, and that not only the ambulacra, but also the nerve cords, meet beneath it. It was this structure principally which led us to the assumption that the central plate represented the five orals collectively, and that the four large proximals, and two smaller ones, were interradial "vault" plates, corresponding with the first interradials of the abactinal side. This seemed to us the more probable, as in the dorsal cup a division of the first interradial into two halves by an anal plate is a frequent occurrence among Palæozoic Crinoids. It also seemed to explain why in *Haplocrinus* and allied forms, in which there is no anal plate, the central piece seemed to be surrounded by five plates instead of six, supposing, as before stated, that *Haplocrinus* had a small oral surrounded by five interradial plates, and *Allagecrinus*, *Coccocrinus*, and *Culicocrinus* five interradials, but no orals. In this we differed from Götte, Carpenter, Zittel, and Neumayr, who all agreed that the *Scheitelplatten* were the orals.†

This was the state of the question in 1888, when we came into possession of a very large number of fine specimens of *Haplocrinus mespiliformis* in various stages of preservation, and found to our astonishment that such a thing as a "central" plate does not exist in the genus. We now saw that the ventral disk consists of but five large plates; that we had mistaken a mere fracture for a suture; and that the part which we supposed to be a separate piece was a tongue-like prolongation of the posterior plate, projecting in between the other four plates, and sometimes surmounted by a small node (Plate III., Fig. 12*b*). This discovery left no room for doubt that the large ventral plates of *Haplocrinus*, and of the Laviformia generally, actually represent the five plates composing the unopened oral pyramid of the Pentacrinoid larva before it moved away from the radials, as had been contended by Carpenter and Gœtte.

So long as a central plate was recognized in *Haplocrinus*, we saw good reason to believe in the existence of a similar plate in other groups of the

* Revision, Part III. Plate VII. Figs. 2, 3, 4, 5, 6, 8, 9, 10, and Plate VIII. Figs. 1 and 2.

† Our theory of the relations of the summit plates, in conformity with these views, was discussed in the Revision, Part III. pp. 44 to 59, and afterwards in greater detail in our paper on the Summit Plates, in the Proceedings of the Academy of Natural Sciences, Philadelphia, March 29, 1887.

Palæocrinoidea; but as soon as it appeared that there is no such plate, it occurred to us that the plate, so apparently central in many Platycrinidæ and Actinocrinidæ, might be a posterior oral, pushed inward to a central position by anal structures. This interpretation seemed to us one of the greatest force, more likely than any other to answer the conditions of a valid homology, and to remove the principal objections that had been brought forward by Carpenter and ourselves respectively to other theories.

The idea of referring the plate to the orals was not altogether new. We had already taken it into consideration before we knew the real structure of *Haplocrinus*, and alluded to it in the Revision, Part III, p. 56, as follows: "A far less objectionable interpretation of the central plate than that given by Carpenter would be to regard it as a posterior oral. In this case the orals would be represented by five plates, and not by six; the anus would be placed outside the oral ring, and the radial dome plates would occupy the same position towards the orals as the calyx radials toward the basals. But it would place the mouth underneath the posterior oral, and it offers no explanation of the central piece in *Haplocrinus*." The last of these difficulties which then seemed so serious was met by the elimination of the mythical plate in *Haplocrinus;* and the first was destined to be perfectly cleared up by the recovery of a new fragment from the scattered pages by which Nature unfolds her palæontological story to us.

While writing up the observations which we had made on *Haplocrinus*, we made another still more unexpected and striking discovery, which in our opinion settled the oral question in conformity with the last mentioned suggestion beyond all controversy. Up to that time the ventral structure of the Ichthyocrinidæ had been almost totally unknown. By extraordinary good luck we obtained a specimen of the genus *Taxocrinus* with the ventral disk in almost perfect preservation, and after carefully cleaning the specimen, we found that it had *an external mouth, surrounded by five parted oral plates, with the ambulacra converging to it, and passing in between the orals.* (Plate III., Fig. 11.)*

The middle of the disk is occupied by five rounded or very obtusely polygonal plates, interradially disposed, rather oval in outline. The two antero-lateral plates are tolerably good-sized, and the postero-lateral ones slightly smaller. The posterior plate is nearly three times as large as any

* A full account of this unique specimen was given by us in a paper, "Discovery of the Ventral Structure of *Taxocrinus* and *Haplocrinus*, and Consequent Modifications in the Classification of the Crinoidea." Proceed. Acad. Nat. Sci. Phila., Nov. 27, 1888.

of the others, and almost twice as long as wide, extending well in between the two postero-lateral plates.

The positions of these plates are relatively identical with those of the five plates at the summit in certain forms of *Platycrinus*, such as are illustrated on Plate III., Figs. 16 and 17, except that the plates of *Taxocrinus* do not meet in the centre, but leave a slightly excentric, obtusely pentagonal oral opening, transversely elongated, its longest side next to the posterior plate. Into this opening, which is deep, the ambulacra converge, and turn downwards at the five corners.

That the five plates of this specimen, although somewhat unequal in size, represent morphologically the five orals of the recent genera *Rhizocrinus*, *Hyocrinus*, and *Holopus*, nobody will deny after seeing the specimen. And a comparison of these plates with the so-called central plate and four large proximals in *Platycrinus*, *Actinocrinus*, etc., leaves no room for doubt that these are likewise true orals. The arrangement of the plates in the different groups is practically the same; the only difference is that in some they are less symmetrically disposed than in others. In *Taxocrinus*, the anus is well removed from the oral centre, which accounts for the fact that the arrangement of its orals is rather more symmetrical than in most of the Camerata, in which the anus is more or less subcentral, and surrounded by heavy, rigid plates. That the amount of asymmetry depends upon the condition of the anus is clearly shown by the figures on Plate III. When the anus is excentric, and its plates are small, the arrangement of the orals is comparatively symmetrical; but when it is subcentral, and especially when it is extended into a large tube, the orals are pushed over to the anterior side. In *Haplocrinus*, in which the anus penetrates the orals, and in *Coccocrinus*, in which it occupies the arm regions, the oral pyramid is naturally about symmetrical. It is now easy enough to understand how a set of five plates, symmetrically disposed over the mouth, could be so altered by the introduction of anal plates as to bring the mouth and centre of radiation beneath the posterior plate. By the encroachment of the anal plates the posterior oral was pushed to a central position, and thereby the mouth came to be placed beneath that plate.

The above explanation of the orals in the different groups met the prompt approval of Carpenter, and this ended a long controversy which had been going on between us for over six years. The orals were found at last to consist of four of the proximals which he had claimed, with the addition of the so-called central plate which we had contended for.

It remains to consider the views of Neumayr. As already stated, he agreed with Carpenter that the *Scheitelplatten* of *Haplocrinus*, and the six proximals of the Camerata, represent the orals. He also believed in the presence of a central plate within the oral ring in both groups. But he differed both from Carpenter and us as to the plates representing the orals in the Cyathocrinidæ.

The structure of the ventral disk of *Cyathocrinus* exhibits considerable variability, and a comparison of the various plates among the different species is by no means an easy matter. As a rule, there are four large interradial plates located ventrally, resting upon the inflected upper edges or limbs of the radials, and at the posterior side two narrow longitudinal strips, which enclose a large, perforated madreporic plate lying in front of the ventral sac, and whose lower (outer) edge is in contact with the sac. The plates are laterally united by suture, and leave five well defined grooves which are occupied by the ambulacra. Within these plates, towards the oral centre and covering it, there is a variable number of other large plates, often of the most irregular arrangement, varying in form even in the same species, and in some cases exhibiting the asymmetry of the orals in the Camerata. The difficulty of ascertaining the morphological relations of these plates in the different forms is increased by the fact that the surface of the outer plates — those nearest the radials — is covered by numerous minute perisomic pieces, interposed between the ambulacra. The ambulacral plates consist of side plates and covering pieces.

Neumayr * speaks of only one ring of plates, resting against the radials and surrounding the mouth, and he assumes that the disk of *Cyathocrinus* is morphologically in the condition of *Haplocrinus*, except that the ambulacra in the latter are subtegminal, but tegminal in the other. We have illustrated on Plate III the ventral structure of *Cyathocrinus* by a series of specimens of different geological ages, and in various stages of preservation, which show that the disk is composed of two sets of plates, the one within the other, and that in cases where but one ring is visible the plates of the second are covered by other structures, or have been resorbed, or are not preserved in the specimen. It is evident that Neumayr has in some instances confounded the plates of one ring with those of the other.

Examining first the two specimens of *C. Gilesi* (Figs. 1 *a*, *b*), there appears to be but one ring of plates, and these rest against the radials. In Fig. 1 *a*

* Die Stämme des Thierreiches, pp. 449–452.

those plates are completely exposed, in Fig. 1 *b* partly covered by marginal pieces; but in both of them there is at the middle of the disk a moderately large vacant space, which in perfect specimens is tightly closed by additional plates. *C. brevisacculus*, Fig. 2, has two rings of plates: an outer one, composed of five subtrigonal pieces, of which the posterior one is largest and perforated, and an inner one, composed of five pairs of plates nearly as large as the former but of variable size and form, which meet in the centre, so as to close the mouth and peristome. The ambulacra are exposed all along the plates of the outer ring, but are covered by the plates of the inner. In *C. nodosus*, Fig. 3, and *C. multibrachiatus*, Fig. 4, the four large interradial plates above the radials, which in the preceding figures are wholly or partly exposed, are completely hidden from view by small marginal pieces. The middle of the disk is covered by a number of rather large pieces, even more irregular in their arrangement than those of *C. brevisacculus*. The ventral disk of *Euspirocrinus spiralis*, Fig. 5, has at four sides a very large, convex interradial plate, and at the posterior side an unusually large ventral sac, with a small madreporite at its base; the ambulacra are tegminal; and the median portions of the disk are closed by moderately small, elongate plates, arranged in rows with the side pieces, which meet in the centre. Very different is the disk of *Cyathocrinus alutaceus*, Fig. 6, which has at the summit five large plates, in form and arrangement resembling the orals of *Platycrinus*. The posterior one is largest, subcentral in position, and pushed in between the other four. There are no grooves along the lateral margins of the plates, the ambulacra being subtegminal; but the re-entering angles at the lower end enclose five well proportioned radial dome plates.

Comparing the summit structure of *C. alutaceus* with that of the Camerata, it is quite evident that the five large plates of Fig. 6 represent the so-called central plate and the four larger proximals. This was also the opinion of Neumayr; but while we take all five plates to be orals, he clung to the idea of a central plate, and recognized six orals, assuming that two of the radial dome plates represented the posterior oral. We do not see how these plates, which occupy the median portions of the disk and cover the mouth and ends of the ambulacra, can be the morphological representatives of the plates which in Figs. 1, 2, and 5 rest upon the radials. Neumayr took the two structures to be equivalent, while we believe that the plates of the former represent the orals, and that the latter are accessary pieces of a similar origin to the interradial plates of the Platycrinidæ.

According to Neumayr, the disk of *Cyathocrinus* is composed of five large plates, which, like the *Scheitelplatten* of *Haplocrinus*, abut against the radials. The plates, he thinks, are in sutural contact laterally, but leave at the summit a large space for the mouth. The ambulacra are exposed upon the surface, resting within the deep grooves, formed along the lateral margins of the plates. They extend from the mouth to the bases of the arms, and are covered by small plates, which project inward over the peristome, and close the mouth externally. The small marginal plates, which, as he states, in some species extend over the whole disk, he takes to be "eine secundäre Wucherung" of the side and covering pieces.

His description does not agree with our idea of *Cyathocrinus;* it comes closer to the structure of *Euspirocrinus spiralis*, from which it was probably made. The latter really seems to have but one set of large plates upon the disk, which touch the radials, and enclose at the summit moderately small plates, which may be ambulacral pieces; but the former are not orals. *Cyathocrinus Gilesi*, as represented in our figures, has also but one ring; but there is a large vacant space at the middle, which was evidently closed in more perfect specimens by an inner ring of plates, as in the other species. *C. brevisacculus* has an outer ring of plates and an inner one, and the ambulacra, which are exposed upon the former, are hidden by the latter. In *C. multibrachiatus* the outer ring is covered by marginal plates, the inner represented by a few irregular, large pieces, scattered upon the surface, and intermingled with ambulacral pieces. This specimen was illustrated by Neumayr on page 473, from our figure in Part III of the Revision, and he must have taken the irregular inner pieces for the orals, for only in this way can we understand the explanatory remarks accompanying the figure. He says: "Wachsmuth and Springer figure a most remarkable example of *Cyathocrinus multibrachiatus*, in which, as they show, the orals (summit plates) are in process of resorption, and in part replaced by small plates." In *C. alutaceus* also, he took the inner plates, which in this species are unusually large and regular, for the orals, and for the homologues of the outer plates of *C. malvaceus*,* *C. Gilesi*, and *C. brevisacculus*.

* Neumayr gave (Stämme des Thierreiches, p. 450), after Meek and Worthen, two figures of the ventral surface of this species: Fig. 2, representing the "Kelchdecke"; Fig. 3, "Dieselbe, nach Entfernung der Deckplättchen." The former has five large interradial plates, with a vacant space in the centre, much larger than that of *C. Gilesi*, and the ambulacral grooves are exposed. In the latter the centre is closed by seven plates, almost as large, and as regular in their arrangement (a central plate surrounded by six proximals), as in *C. alutaceus*. That he took these plates, contrary to those of *C alutaceus*, for covering pieces, extensions from the ambulacra, and not for orals and central plate, is clearly indicated by the explanation of the figures.

Neumayr's interpretation of the plates meets with serious difficulties. There are in *Cyathocrinus* undoubtedly two sets of plates; the one occupying the centre of the disk, and covering completely mouth and peristome, without grooves, and with the ambulacra subtegminal; the other occupying the outer margins of the disk, grooved, the ambulacra tegminal, and covered over by perisome which extends inward and closes the mouth. He undertook to explain these difficulties by palæontological development, but overlooked the fact that in the ontogeny of recent Crinoids the perisome is introduced above the radials, and between the orals, and that the latter are carried relatively inward. The same mode of development we find in the phylogeny of fossil forms; the orals, with the introduction of interradial plates, are moved to the centre of the disk, and either *cover* the mouth or *immediately surround* it. That is the case in the Camerata and the Articulate Ichthyocrinidæ, and there is no reason to doubt that it is the same way in the Cyathocrinidæ. In the Larviformia, however, in which there is no perisome, the orals rest against the radials, but also cover the mouth, as they do in the Pentacrinoid larva.

We believe with Neumayr that the differentiations among the species which we have noticed in the disk of *Cyathocrinus* are modifications due to palæontological development. It seems to us that the orals throughout this genus are more or less in a state of resorption, more advanced in one species than in another, and even varying in degree in the same species. From this we conclude that the Silurian *C. alutaceus*, in which the orals are almost or wholly intact, represents the more primitive form of the genus, and *C. malvaceus, etc.*, a later stage; and that *Euspirocrinus*, in which the orals are apparently completely removed, and the ambulacra thereby brought into view upon the disk, represents a more advanced stage than either species of *Cyathocrinus*.

For proof that a resorption took place in the same species, we refer to the specimen of *C. alutaceus*, Fig. 7, which differs essentially from Fig. 6. It is also proved by numerous specimens in our collection,* which show distinctly that the orals are proportionally larger, and more regular in their arrangement in young specimens than in the adult. In one of the specimens, not larger than a good-sized pea, they occupy fully two-thirds of the disk, being

* We have from sixty to seventy specimens in most excellent preservation, representing five species, in which we exposed the disk by removing the arms. Most of them came from Indian creek, Ind. (Keokuk group), though some are from Burlington, and a few from Crawfordsville.

thus considerably larger than the plates occupying its outer margins, which are also exposed in that specimen.

We thus find persistent among Palæozoic Crinoids all the phases through which the orals pass in their individual growth in recent forms, from the early Pentacrinoid larva of *Antedon* to the adult *Hyocrinus* (Plate III, Fig. 10) in which they are very large, and *Calamocrinus* * in which they are extremely small; and we find the plates in process of resorption and entirely removed from the system.

We further find that the orals in all Crinoids, recent and fossil, when represented, occupy the centre of the disk, immediately surrounding the mouth or covering it, and that the orals of the earlier forms differ from those of the recent only in their asymmetrical arrangement, caused by the greater rigidity and more extensive development of the anal structures.

### B. *Mouth and Ambulacra.*

The presence of a single aperture in the disk of Palæozoic Crinoids induced the earlier writers to suppose that this opening, although interradially disposed, served both as mouth and vent. Later observations, and a better knowledge of the general structure of recent Crinoids, their mode of feeding and the nature of their food, have shown conclusively that this opening is not the mouth, but the anus, and that the mouth in most Palæozoic forms was subtegminal.

The mouth of all Crinoids is directed upwards, being placed in the centre of radiation, but does not in all of them occupy the centre of figure. It is very frequently subcentral, and may be altogether excentric. The latter is the case in the asymmetrical genus *Actinometra*, and to some extent in all Fistulata, in which the posterior side of the disk is extended into a large tubular or sac-like prolongation. It is subcentral in most of the Camerata, and central in all known recent forms, *Actinometra* excepted.

The ambulacra occupy the grooves along the ventral side of the arms, and extend from the tips of the pinnules to the mouth. Their proximal ends are either exposed upon the disk, or covered wholly or in part by plates of the tegmen. Entering the mouth there are five main trunks, which ramify so as to give a branch to every arm and pinnule. The upper face of the ambulacra is occupied by the food grooves, which are roofed over

* A. Agassiz, Memoirs Mus. Comp. Zoöl., Vol. XVII, Plate 6, Figs. 1 and 2.

by the covering plates, and frequently bordered by small side pieces; the former arranged alternately with each other and with the side pieces. In the living animal the food grooves are lined by cilia, which are kept in a continual vibratory motion so as to produce currents of water, by means of which any particles of food that happen to fall upon the grooves are transmitted toward the mouth. Beneath the food groove lies a nervous band, and beneath that a blood vessel, which in turn is followed by the genital canal, and this by the subtentacular canal; the genital canal, which is quite small, occupying only the median portions. The subtentacular canal, also known as the ambulacral canal *proper*, from which branches are given off to the tentacles, communicates with the annular vessel situated in the lip around the mouth. Beneath the ambulacra is the axial canal,* which occupies the bottom of the arm grooves, frequently piercing the body of the plates. This canal is connected with the chambered organ at the lower part of the dorsal cup, and contains the axial cords, which, as now generally admitted, control the movements of the arms and pinnules; while the nervous apparatus beneath the food grooves has no connection with the muscles, and no influence upon the movements of the skeleton.

The ambulacra of fossil Crinoids are rarely observed, and their presence is usually only indicated by the open grooves within the arm skeleton. In some cases, however, the side and covering pieces of the disk, and occasionally those upon the arms, are preserved.

In all recent Crinoids the covering pieces are movable from the tips of the pinnules to where they enter the mouth, but they are rigid upon the disk in Palæozoic species, with perhaps a few exceptions. In the Camerata, and especially among the Platycrinidæ, they are often heavier and larger than the interambulacral plates; while in other groups, and chiefly among Silurian forms (Plate III. Fig. 11), they are quite small. The larger the plates, the more irregular they are in their arrangement, and the smaller the most regular. It is also noteworthy that the ambulacra may be tegminal or subtegminal in the same genus. Those of the Platycrinidæ, as a rule, are tegminal, those of the Actinocrinidæ generally subtegminal; but also the opposite is the case in genera of both groups.

There is considerable variability in the extent to which the ambulacra are exposed upon the surface. In the Camerata they never extend out to the centre of the tegmen, their proximal ends being always hidden by the

* This canal is also known as the "Dorsal" canal, and as the "Cœliac" canal.

orals, and when these are wanting, by some of the interambulacral plates; or by both, in which case only small portions of them are seen near the arm bases. In the Fistulata, the disk ambulacra are either altogether tegminal. or their ends are covered by the orals. In the Ichthyocrinidæ, so far as observed, and in recent Crinoids, they extend to the mouth, whether orals are represented or not; but while in *Taxocrinus* (Plate III. Fig. 11) they are in the same plane with the orals, and are attached to them laterally, in recent forms, in which the orals are opened out, they are deeply inserted between the interambulacral plates, so as to be almost obscured.

The disk ambulacra of the Camerata, if tegminal, form a component part of the tegmen, being suturally connected with the interambulacral plates, and with the orals. In the Cyathocrinidæ, however, and probably in other Fistulata, they rest upon large interradial plates, and between the small marginal pieces which cover the surface of the latter. In the Ichthyocrinidæ and recent Crinoids, they are separated by minute interambulacral pieces.

The ambulacra of the Camerata rarely have any side pieces, these being represented, so far as known, only in *Megistocrinus* (Plate XLVII. Figs. 7 and 8 *a*, *b*), in *Cactocrinus* (Plate LVIII. Figs. 7 *a*, *b*), and in *Lyriocrinus* (Plate XI. Fig. 4 *c*). They are present, however, in most Fistulata, but absent in the Larviformia.

That the covering pieces in the disk of *Cyathocrinus*, as suggested by several writers, were movable, so as to expose the food grooves, seems to us improbable, although there is no serious objection to it from a morphological point of view; but the perfect preservation of the plates in so many of our specimens seems rather to indicate that they were rigid. They may have been movable in groups in which the mouth is opened out, but where it is closed they were probably rigid throughout the disk.

In some of the Camerata in which the primary arms are developed into tubular appendages, and secondary arms are given off at the sides, as in *Eucladocrinus* (Plate LXXIII. Fig. 3, Plate LXXIV. Fig. 4), and *Steganocrinus* (Plate LXI. Fig. 1 *e*), the covering plates of the main arms are almost rigid to the full length of the ray, and only those of the side arms and their pinnules were movable. But it must be remembered that these appendages are practically extensions of the calyx.

Subtegminal ambulacra, so far as we know, occur only among the Camerata and Larviformia. In the former there are frequently along the inner floor of the tegmen deep grooves or ducts, which are formed either by a folding of the test or a thickening of the plates, and which proceed from the middle of the floor to the arm openings (Plate V. Figs. 13, 14, 15, 16, and 17). Within these grooves are lodged the ambulacra, which are represented by a skeleton of radiating tubes, following the inner surface of the disk (Plate V. Figs. 1 and 10; Plate IV. Fig. 8). The tubes are composed of four rows of plates, two below and two above, both alternately arranged, the former probably representing subambulacral pieces, the latter covering plates. The skeleton has never been found completely preserved, but enough is shown to indicate that the tubes do not extend out to the centre, but meet in an annular vessel surrounding the mouth. This at least seems to have been the structure of *Macrocrinus verneuilianus*, in which an almost circular vessel has been observed beneath the centre of the disk at some distance from the inner floor (Plate V. Fig. 8). No ambulacral tubes are attached to it in the specimen, but it has five openings in a radial direction, which evidently communicated with the ambulacral vessels. The ring is rather large, and is placed around the contracted upper part of the convoluted organ, which is also preserved in the specimen.

The direction of the ambulacral tubes and their branching is well observed in natural casts, in which, after the calcareous parts are removed, the ducts of the tubes are represented by filiform elevations upon the surface (Plate IV. Figs. 1, 2, 3, 4, 5), sometimes even showing impressions of ambulacral pieces. It also appears from these casts that the ambulacra in some cases rested directly against the tegmen, and in others lay at a distance from it, only touching the test at the arm bases. The latter was undoubtedly the case in the interesting specimen of *Platycrinus* (Plate IV. Fig. 6), in which the ambulacral plates are clearly marked near the margins of the disk, while no traces are found of their inner portions. If the ambulacra had touched the inner floor, the delicate markings of the disk plates would not be in sight, but instead of them traces of the tubes would appear upon the surface. This is corroborated by the cast of *Dorycrinus* (Plate IV. Fig. 5), in which the ambulacra are visible to the outer edges of the orals, but disappear underneath them. Also in the beautiful specimen of *Cactocrinus proboscidalis* (Plate V. Fig. 10), where the tubes are removed from the floor,* and in *Teleiocrinus* (Plate IV. Fig. 1), and in *Cactocrinus glans*

* Neumayr, who knew this specimen from Meek and Worthen's figure, expressed the opinion that a settling of the tubes probably took place after the death of the animal. He based this opinion upon the structure of the casts, in which he supposed the ambulacra were always exposed at the surface, which, as we have stated, is by no means the case.

(Plate IV. Fig. 8). That they were attached to the tegmen in many of these Crinoids, and probably in the majority of them, is also suggested by the presence of the so-called radial dome plates.

The name "radial dome plates" was given by us to a set of large plates in the tegmen, radially disposed, and occupying the regions between the orals and the arm bases. The plates are generally larger than the surrounding ones, and quite frequently nodose. They were regarded by us, and also by Dr. P. H. Carpenter, until quite recently, as the actinal representatives of the radials, but later investigations prove they are highly differentiated covering pieces. The plates are either followed by two series of regular covering pieces, and pass out from between the angles of the orals, or they are to a certain extent isolated, surrounded by other plates, and succeeded by similar plates of higher rank. The former is the case in most of the Platycrinidæ and Hexacrinidæ, the latter among the Actinocrinidæ and Rhodocrinidæ with subtegminal ambulacra. That the plates in the former case are simply covering pieces, is readily perceived by examining those species in which the plates are but little disturbed. Taking *Platycrinus* and *Dichocrinus*, we find in both genera certain species in which two series of small, almost regularly arranged, alternating pieces pass out from the orals to the arms. Such is the case in *Platycrinus symmetricus* (Plate LXIX. Figs. 1 *b*, *c*), in *Dichocrinus polydactylus* (Plate LXXVII. Fig. 1 *b*), and in *D. lachrymosus* (Plate LXXVII. Fig. 2 *c*). Similar plates under similar conditions also occur in the Silurian *Marsupiocrinus* (Plate VIII. Fig. 15, and Plate LXXV. Figs. 16 *b* and 18), and among Silurian genera of other groups. There are no large plates next to the orals, and hence no radial dome plates, unless they are represented by the small proximal plates. From this structure to that of *Platycrinus discoideus* (Plate LXVI. Fig. 10 *b*), and *P. Halli* (Plate LXXII. Fig. 7 *a*), there is but a short step. The plates in question are comparatively larger, especially the proximal ones, and arranged alternately, although not so regularly as in the former species. In *Platycrinus burlingtonensis*, however (Plate LXIX. Fig. 3 *c*), and *P. Yandelli* (Plate LXVIII. Fig. 3 *c*), there is generally a large plate followed by smaller ones, and the alternate arrangement of the plates actually commences at the arm bases. If we had only the latter species, we might perhaps be justified in regarding those proximal plates as independent structures; but comparing them with those of other species in which the arrangement is more regular, it becomes evident that they are all nothing but covering pieces, which gradually in geological time changed their character.

The "radial dome plates" of the Actinocrinidæ and allied forms are generally larger than any of the surrounding plates, often nodose, and sometimes extended into long spines. They are not followed immediately by covering pieces, as already stated, and are placed at some distance from the orals, — occupying in the simpler forms with but two arms to the ray almost the outer margins of the tegmen (*Agaricocrinus*), — directly over the point at which the bifurcation of the ambulacra takes place. When there are four arms to the ray, they are removed relatively further inward, and are followed by two similar but smaller plates of higher rank. But when there are three arms to the ray, there is only one such plate, which is directed to the side where the bifurcation is, the opposite side of the plate being followed by the regular covering pieces of the arms.

From this structure we may infer that the so-called radial dome plates with subtegminal ambulacra are axillaries, and if they represent, as we have reason to believe, modified covering pieces, that they are the plates from which the ambulacra bifurcate. In this view it is quite suggestive that the axillary plates of the ambulacra are frequently protuberant. In *Eucladocrinus millebrachiatus* (Plate LXXIII. Fig. 1), they are all along the main arms strongly nodose, and if the ambulacra of this species had been covered by other plates, the tips of the axillaries naturally would project above them and be exposed upon the disk. In this way the radial dome plates may have originated, so that afterwards the upper portions developed to larger size, and finally become independent plates. This explanation seems to us most probable, and it was favorably received by Carpenter.

The Palæontological evidence indicates that in the earlier Camerata, as in the young specimen at some time, the ambulacra were exposed upon the disk. In most of the Silurian forms they took part in the tegmen, and their covering plates, as a rule, were more regular in their arrangement than in those of later epochs. In the Carboniferous, with the exception of the Platycrinidæ, Hexacrinidæ and Acrocrinidæ, the ambulacra are almost exclusively subtegminal, and the whole disk assumes that extravagant form which led at one time to the belief that it represented an entirely different structure.

## III. SUPPLEMENTARY PLATES.

### A. *The Distribution of the Plates, and their Relations in the Different Groups.*

The supplementary plates comprise all limestone particles between the basals and orals, and intervening between the rays and their subdivisions. They are divided into interradial, interaxillary, and anal plates. The interradial plates, comprise as a general term all plates between the basals and orals, interradially disposed. Some of them are distinguished as interbrachials, others as interambulacrals. The interbrachials are confined to the dorsal cup. The interambulacrals occupy the spaces between the ambulacra. The interaxillaries, consisting of the interdistichals and interpalmars, are located within the axils of the second, third, and succeeding orders of brachials respectively. The anal plates are restricted to the posterior interradius supporting the anal tube. Another system of small plates occurs in the Acrocrinidæ, where they form a wide belt intermediate between the basals and radials.

In nearly all Crinoids, recent and fossil, in which the free arms do not start directly from the radials, the lower arm joints are incorporated into the calyx, either by soft tissues or by means of plates. The latter are exceedingly variable in form and character, being in some groups well developed and rigid; while in others they are irregular, ill-formed pieces, or mere limestone particles, resting within soft tissues. The great variation observable in the structure of the plates among different groups led to the belief that the rigid and regularly arranged pieces, which are so characteristic of the Camerata, did not belong to the same system of plates as the irregular, small pieces which unite the rays of recent Crinoids; and Dr. P. H. Carpenter applied to the former the term "calyx" interradials, as opposed to the interradial plates of the "disk."

A somewhat similar distinction was made respecting the plates which form the ventral pavement. The heavy, rigid pieces of Palæozoic forms were called "vault" plates; and the small, irregular pieces of later and recent Crinoids, "perisomic" or "disk" plates. The term "vault" was generally applied in cases where the mouth and food grooves are permanently closed, and "disk," where the mouth and food grooves are open.

In the Camerata, the interbrachials are nearly always arranged on a definite plan, and are stout, large, and united by close suture, making the whole test, to the bases of the free arms, extremely rigid. The interbrachial plates of the regular sides generally commence with one plate, which in most families rests upon the radials and between the costals. It is usually followed by two in the second row, and two, three, or four, according to species, in any succeeding ranges there may be. The posterior interradius is frequently wider, and divided vertically into two halves by a continuous or interrupted series of anal plates; but it may be constructed like the other four. In the Platycrinidæ and Hexacrinidæ the first row consists of three pieces, which are for the most part neither entirely interbrachial nor entirely interambulacral. In the Rhodocrinidæ the first plate interradially disposed goes down to the basals, thus separating the rays to their full length. This first plate is therefore not strictly interbrachial in position, as it lies below the horizon of the lowest brachials; nevertheless it unquestionably belongs to the same system of supplementary plates, which in this group extend down to a position between the radials. There is some variation in the extent to which the radials are parted by these intervening plates. In some species of the Rhodocrinidæ, exceptionally, the radials are only separated to half their length, the variation occurring among different specimens of the same species, and even in different areas of the same specimen. We find it convenient to call these plates interposed between the radials "first interradials" where it will avoid circumlocution. The interbrachial and interaxillary plates of the Reteocrinidæ, contrary to those of all other Camerata are ill-formed, and irregularly arranged.

The interradial plates occupying the ventral side of the calyx are as rigid as those of the dorsal side, but are as a rule less regularly arranged. They either extend up to the orals, or, when these are not represented, and the ambulacra are subtegminal, they cover the whole tegmen, leaving no opening except the anus.

At the inner floor of the tegmen, we find in most of the Actinocrinidæ and Batocrinidæ shallow grooves or open galleries, which are well shown by the natural casts figured on Plate IV. Figs. 1, 2, 4, 5, 6, and 7, in which they are represented by the elevations. These galleries pass out from near the centre to the arm bases, and lodge the ambulacral tubes. Alongside of them, and sometimes covering them, there is frequently in both families — but, so far as observed, only in certain genera — what appears to be a second integument (Plate V. Figs. 13, 15, 16, and 17), lying parallel to the inner floor, which was formerly supposed to represent the ventral disk. The outer integument was regarded as a structure *sui generis*, to which the term "vault" was applied. The inner integument appears at first sight as if composed of independent, ill-formed pieces; but on closer inspection it is found that these so-called plates are extensions from the plates above, and continuous with them. Each lower part is connected with the corresponding upper one by small surfaces or pillars, and joining by its edges with other like plates, leaves open spaces or meshes along the sides. The inner portions constitute a kind of internal lining or network, extending from the first costals and first interbrachials uninterruptedly to the margins of the orals. In some specimens only the pillars are preserved, the lateral extensions of the plates being wanting; while in others the floor is almost entirely smooth. The latter is the case in *Cactocrinus proboscidalis* (Plate V. Fig. 10); while in *Teleiocrinus rudis* (Plate V. Fig. 16), and in the specimen of *Dorycrinus* (*ibid.* Fig. 13), the grooves are formed into well defined tunnels. A further indication that there were probably two integuments in some of the Camerata at least, seemed to be presented by the ventral structure of *Siphonocrinus armosus* from the Niagara group (Plate XIX. Figs. 3 *a*, *b*, *c*). This species, so well known from natural casts, has a large, trumpet-shaped, subtegminal anal tube, which crosses the mouth, overlies the upper ends of the ambulacral tubes, and is continued subtegminally all the way to the anterior side of the calyx, even beyond the arm regions, where it bends outward. The case is best illustrated if we imagine the disk of a recent Crinoid, with an anal tube like that of *Antedon regalis* (Chall. Rep. on the Comat., Plate XLVI. Fig. 2), extended all the way out to the arm bases of the anterior ray, and covered by a vault.

It seemed hard to account for the facts presented by these cases, except by the presence of two distinct structures covering the body cavity; and upon these specimens principally we formed the opinion, in the first instance, that the Camerata had a vault and a subtegminal disk, and that the vault was a structure without a parallel in recent Crinoids. The evidence appeared to be conclusive that the disk was subtegminal, in some groups at least, and this, which had been generally acknowledged by leading authors, led us to believe that in all Camerata the disk was roofed over by a vault. In fact this conclusion seemed to be corroborated by the nature of the plates, which, although varying considerably in size and number, are arranged in all these Crinoids on the same general principle, forming in all of them a compact, rigid test, with the mouth and food grooves perfectly closed.

Carpenter* held the same opinion as to the vault of the Actinocrinidæ, but he believed that the "vault" of a Platycrinoid "corresponds collectively to the orals, interradials, ambulacral and anambulacral plates of Neocrinoids." He agreed with us† that the calcareous network beneath the "vault" of an *Actinocrinus* "corresponds to the limestone particles on the surface of the internal casts, and represents the anambulacral plates developed in the perisome of recent Crinoids." He also admitted "the complete resemblance between the ventral perisome of a recent Crinoid and the upper surface of the body beneath the vault of an *Actinocrinus*." "The vault and ventral disk," he said, "are to my mind entirely distinct structures." Of the vault, he said further (p. 172): "I believe the oral or actinal system forming the vault of *Actinocrinus* to have been developed on the left larval antemer, in exactly the same way as the apical or abactinal system is developed on the right; but the oral system, instead of being limited to five oral plates, as in Neocrinoids, reached a very extensive development, so that in its completest form it represents such a parallel to the apical or abactinal system as is to be met with in no other Crinoid." From these passages and others in the Challenger Report, it appears that Carpenter, as well as we, supposed that in *Actinocrinus* all plates of the calyx up to the arm bases were abactinal, and all constituting the ventral side actinal; not only the orals and radial dome plates, but also the so-called interradial dome plates or interambulacral pieces.

We retained the above mentioned opinion until 1881; but afterwards our views were materially changed respecting the interradial dome plates,‡ which we no longer regarded as actinal structures, but took to be continuations of the interradial plates of the dorsal cup, and as fundamentally identical with them. In considering the matter in the first place, we had not overlooked the fact that in many of these Crinoids, throughout different groups, the covering plates of the ambulacra are exposed at the surface, and as such would form a part of the "vault."

It is a striking fact, in the Crinoids as elsewhere, that some characteristics which are of the greatest importance from a morphological point of view, prove to be of comparatively little value for classification. This is the case in a marked degree with the ambulacra of the Platycrinidæ and Actinocrinidæ, which are found to be tegminal and also subtegminal. In the Platy-

* Chall. Rep. Stalked Crinoids, pp. 172–180.
† Chall. Rep. Stalked Crinoids, pp. 165, 166.
‡ Revision, Part III. pp. 16–27 (Acad. Nat. Sci. Phila., pp. 238–249).

crinidæ, the covering pieces are generally exposed in the calyx, while in the Actinocrinidæ they are as a rule hidden from view. But occasionally the opposite is the case, and even among species of the same genus. *Actinocrinus stellaris*, from Belgium, has well defined covering pieces passing out from the outer edges of the orals; while almost every other species of *Actinocrinus* has in place of them radial dome plates of the first, second, and third order, according to the number of bifurcations in the calyx. *Physetocrinus*, which is but a modified *Actinocrinus*, has in some species orals and radial dome plates; while in others the whole ventral surface is covered with small, irregular pieces. In *Actinocrinus multiradiatus*, the entire tegmen consists of only a few unusually large interradial plates, which interlock with those of the dorsal cup. But the interradials in most of the Actinocrinidæ pass insensibly into the tegmen, there being no dividing line; while in *Batocrinus* generally, but not always, the interradials of the dorsal side are distinctly separated from those of the ventral side by the arching brachials, — a structure which led us at first to suppose that the plates of the two hemispheres were morphologically distinct.

Similar variations occur among the plates of the tegmen in the Platycrinidæ and Hexacrinidæ. In some of their species the pavement is made up entirely of massive plates, in others of comparatively thin pieces; while in still others the ventral surface is occupied almost exclusively by the orals. In both groups it is absolutely impossible to draw a dividing line between interbrachials and interambulacrals. The plates constituting the first row, which generally consist of three pieces, are peripheral and partly interambulacral, and those of the succeeding rows strictly ventral. The plates of the second and higher rows, when such are present, interlock with those of the first row, like the interradial plates of the dorsal cup in an *Actinocrinus*.

The condition of the ventral pavement in the Melocrinidæ, Rhodocrinidæ, and Thysanocrinidæ is similar to that in the Actinocrinidæ. Their lower interbrachials are definitely arranged, and there is no line of demarkation between the plates of the two hemispheres, except that produced by the arms, which pass out between them. In the Reteocrinidæ, as in most of the other Silurian Camerata, the whole ventral surface is covered by minute, irregular pieces, and similar plates, with a few somewhat larger ones scattered among them, are interposed between the rays from the basals up.

It seems to us perfectly clear from the structure that all interradial and interaxillary plates, not only in the Camerata, but also in all recent and fossil

Crinoids, where they exist, are auxiliary pieces, which increase by multiplication in the growing animal, filling up spaces between the rays and their subdivisions. They increase primarily in an upward direction, but partly by intercalation, secondary plates being introduced between the primary ones. It is owing to the intercalation of these secondary pieces that the arrangement of the interradial plates in the upper rows is less regular than it might otherwise be. In the simpler forms such pieces are wanting, or only occur close to the arm bases. In some species, however, they are quite numerous in the dorsal cup, as well as in the tegmen, and in the Reteocrinidæ they constitute the greater part of the interradial and interaxillary areas. In this family small pieces continually formed in large numbers in the growing Crinoid along the margins of the radials and brachials, and between the primary interradials, so as to isolate these from their fellows and from the plates of the rays (Plate IX. Figs. 1 *c*, 5 *c*).

The interradial plates, as already stated, are continued into the tegmen. This may be readily perceived in species which have but one or two bifurcations in the calyx; but in the more complex forms the primary structure is frequently obscured by the introduction of secondary pieces, giving the impression that the plates of the two hemispheres were structures morphologically independent. Looking at a specimen of *Strotocrinus*, with a broad flanging rim, its hundred and more arms crowded around it, and its thousands of minute "vault" plates, growing smaller outward, and not connected with the interradials of the dorsal side, it is not surprising that such an impression should be created.

To understand the structure of *Strotocrinus*, we may refer to that of the allied genus *Steganocrinus*, in which in like manner the arms branch off alternately like pinnules from the two main divisions of the rays; but while in *Strotocrinus* the lower parts of the arms are incorporated into the calyx, and form a continuous rim from which the free arms start off, in *Steganocrinus* the two divisions of the rays, bearing their small alternate arms, remain permanently free, and extend out laterally as tubular appendages of the calyx. It is now very significant to find that in *Steganocrinus* the interradials of the dorsal cup meet those of the tegmen in such a manner that it is absolutely impossible to draw a line between the plates of the two hemispheres (*Steganocrinus pentagonus*, Plate LXI. Fig. 3 *b*). This case is the more instructive, because *Steganocrinus*, with its free arms, may be regarded as representing an early stage in the developmental history of *Strotocrinus*.

A structure similar to that of *Steganocrinus* is found in all Camerata in which the arms are free from the distichals up; and from this condition all gradations can be traced to the complex structure of *Strotocrinus*. The plates of the dorsal cup and those of the tegmen are undoubtedly parts of one element; and although they are introduced respectively at the actinal and abactinal sides of the calyx, the plates of the one side cannot be regarded as strictly abactinal, nor those of the other as actinal.

Referring again to *Platycrinus*, Carpenter* said that the series of interradials found in the peripheral portion of the vault (tegmen) — by which he meant the zone between the proximal dome plates (summit plates) in the centre and the calyx interradials (of the dorsal cup) — belong to the same system of interradial plates as the single large interradial in *Cyathocrinus*. And he continues: "I do not myself think that the vault of a *Platycrinite* was exactly of the same nature as that of an *Actinocrinite*, *i. e.* that it covered in the whole of the visceral mass and the ambulacra on its upper surface. For if the alternating dome plates represent the covering plates of recent Crinoids, as Wachsmuth suggests, then all the periphery of the dome, outside the apical dome plates (orocentral and orals), must be the real ventral surface of the body, and not a *tegmen calycis* as in *Actinocrinus*." And in alluding to the tegmen of *Marsupiocrinus*, he said: † "I have a very strong impression that the so-called vault of this genus is really the strongly plated ventral perisome, in the centre of which the remains of the orals (apical dome plates) are perhaps to be found. I cannot see any such essential difference between it and the plated disk of *Pentacrinus Wyville-thomsoni* or of many *Antedons* (Plate XVII. Fig. 6; Plate LV.) as would lead to the supposition that the homologue of the latter is to be sought for beneath the vault of *Marsupiocrinus*." He then alluded to the closure of the mouth, and to the covering pieces of the ambulacra, which may have been immovably closed down over the food grooves, saying: "They were thus converted into tunnels, but were still 'external,' in the sense of not being covered by a 'tegmen,' as those were which formed the tubular skeleton beneath the vault of the Actinocrinidæ." That is to say, in short: Vault and disk are entirely distinct structures; and the ventral surface of one Palæocrinoid represents a disk because the ambulacra are external, while that of another is a vault because they are subtegminal.

* Chall. Rep. Stalked Crinoids, p. 178.
† Chall. Rep. Stalked Crinoids, p. 176.

We have already pointed out that the covering pieces are exposed not only in the Platycrinidæ, but frequently also in other families of the Camerata, — exceptionally even in the genus *Actinocrinus*. If it were true that in Crinoids in which the disk ambulacra are subtegminal, the integument which covers them is a "*vault*," and, on the contrary, in those with ambulacra exposed, or "external," a *disk*, it seems to us that the two forms should be separated as distinct orders, and it would follow that our present classification of the Crinoids is arbitrary and worthless. These considerations produced in our minds a firm conviction that the integument in both cases must represent the same thing, being either a vault or a disk, — the plates either all vault pieces or all perisomic.

In some species of *Platycrinus* the ambulacra make their appearance, not at the margins of the summit plates, but at some point intermediate between the orals and the arm bases, from beneath the upper ring of the interradial plates. In these species, applying Carpenter's interpretation, the lower interradials would be perisomic, for they expose the ambulacra; but the upper ones vault plates, because they do not. In *Pterotocrinus*, the last survivor of the Hexacrinidæ, a very highly differentiated form, the tegmen, according to Carpenter,* "seems to have had a closer resemblance to that of *Actinocrinus* than is the case in most Platycrinidæ, for it had radial dome plates of the first, second, and even occasionally of the third order." In other Platycrinidæ the oral system, he says,† sooner or later came in contact with the alternating series of ambulacral plates. "There was a membranous disk, the radial regions of which were traversed by the ciliated food grooves beneath the ambulacral skeleton above; while the interpalmar regions supported the interradial plates of the vault." Further on he explains that the vault of the Platycrinidæ is not a true vault, or *tegmen calycis*, like that of the Actinocrinidæ, but corresponds collectively to the orals, interradials, ambulacral and anambulacral plates of Neocrinoids; contrary to the vault of *Actinocrinus*, which not only covers in the food grooves themselves, but also their skeleton of alternating plates, together with the origin of the ambulacra and the plated interpalmar areas of the disk.

We never imagined that *Platycrinus* had anything but a membranous disk, which, we thought, was continued underneath the interradial plates all the way to the arm bases. Neither did we suppose it had any further plates above the food grooves than the alternating pieces; nor that the

* Chall. Rep. Stalked Crinoids, p. 177.

† Ibid., pp. 179–180.

latter were true vault plates, as Carpenter inferred we did. We held that while in the vault of the typical *Actinocrinus* the interradial dome plates meet over the ambulacra, in *Platycrinus* these plates opened out so as to expose the covering pieces, and that these were gradually incorporated into the vault. In a typical Platycrinoid, the covering pieces are so modified as to lose almost their original character, being as large and nearly as heavy as the surrounding plates, and they are united with one another, as well as with the latter, by close suture. In some of the later Platycrinidæ they even may have been separated from the food grooves, for in the internal casts they left no impressions; while in casts of *Actinocrinus* from the same localities, and in casts of certain Silurian Platycrinidæ, the outlines of the ambulacra are generally sharply delineated (Plate LXXV. Fig. 14).

Carpenter probably supposed the ventral structure of the Melocrinidæ and Rhodocrinidæ to be in the same condition as that of the Actinocrinidæ and Platycrinidæ respectively, that is, a disk when the ambulacra are exposed, a vault when they are concealed. He alluded to *Glyptocrinus* in connection with the Reteocrinidæ and Ichthyocrinidæ, in all of which the ventral pavement is composed of an immense number of very minute, irregularly arranged pieces. In the Ichthyocrinidæ these plates are traversed by regular rows of alternating pieces, passing out from the oral centre to the arms; in the two other families, however, such alternating plates, when present at all in the tegmen, are found only close to the arm bases. Carpenter says respecting these groups,* "I venture to think that in the case of *Glyptocrinus*, *Reteocrinus*, *Xenocrinus*, and also of the Ichthyocrinidæ, the resemblance to the Pentacrinidæ, Apiocrinidæ, and Comatulæ, is such as to leave no reasonable doubt that the so-called vault of these Palæocrinoids is homologous with the ventral surface of the body in the Neocrinoids." This is true enough as to *Taxocrinus* and *Onychocrinus*, and probably the Ichthyocrinidæ generally, in which mouth and food grooves are exposed, as we have found out from actual observation; but in the case of *Glyptocrinus* and *Reteocrinus*, there is nothing to prove it beyond a superficial resemblance of the plates. Carpenter's argument loses much of its force, considering that among the Actinocrinidæ within the same genus some species have large plates, others very small ones, and the evidence seems rather to prove that either these plates are all disk plates, or none of them are.

* Chall. Rep. Stalk. Crin., p. 185.

Essentially different is the ventral structure of the Fistulata, which have no interradial plates in the dorsal cup, the anal piece excepted; but those plates are extensively developed in the tegmen. Four of the interambulacral spaces are raised but little above the level of the arm bases; while the posterior area is extended abruptly upward, and formed into a sac or tube of various forms, frequently rising beyond the tips of the arms. This sac, which may be regarded as a greatly extended anal area, and probably lodged a large portion of the visceral mass, must not be confounded with the anal tube of the Camerata, which contains simply the rectum. The sac is tubular, balloon-shaped, spiral, or club-shaped, and is generally composed of longitudinal rows of hexagonal plates, which are often pitted at their sides, or perforated by pores.*

The structure at the four other sides of the disk is rarely observed except in the Cyathocrinidæ, in which it was probably more substantial than in the other families. In *Cyathocrinus* it is well shown in our figures on Plate III. Figs. 1, 2, 3, 4, 6, 7, 8, to which we drew attention in our chapter on the orals. There are six plates, interradially disposed, resting against the inflected upper edges of the radials, their lateral margins covered by the ambulacra. Four of them are larger, cordiform, and of equal size; the two others, which lie at the posterior side, are quite narrow, and enclose a large perforated plate, to which we have applied the term *madreporite*. The surfaces of the four larger plates in perfect specimens are roofed over by numerous delicate pieces; while the perforated plate is completely exposed to view.

As to the relations of these plates various conflicting views have been expressed. Wachsmuth, in 1877, supposed that the plates collectively constituted a kind of consolidating apparatus, like that described by Roemer and others in *Cupressocrinus*. We afterwards, supposing that there were five plates, suggested that they were structurally identical with the deltoids of the Blastoids, which at that time were regarded as homologous with the orals of the Crinoids. Similar views were expressed afterwards by Carpenter,

* Mr. Bather is of the opinion that the ventral sac of the Fistulata is not perforated, but only pitted (Geol. Magazine, May, 1891, p. 223, and elsewhere). This may be true as to *Cyathocrinus*, *Euspirocrinus*, and possibly the *Cyathocrinidæ* generally, in which very likely the madreporite performed the functions of the tube-pores; but we have the most complete evidence that among the Poteriocrinidæ, in many cases, the pores pass through the test. In some specimens in which the lateral edges of the plates were exposed perfectly free from the matrix, we have been able to trace the ducts of the pores to the full depth of the plates. They are well shown on Plate VII. Figs. 2*b*, 5, 7, 8, 9. That the openings are not visible in most of the specimens is due to their small size and probably also to the mode of petrifaction.

Zittel, and Neumayr, who all regarded the plates as orals. Plausible as this theory appeared to us at first, it involves serious morphological difficulties; and in 1883, on discovering that the plates consist of seven pieces instead of five, we abandoned it, in which we were followed by Carpenter. Since then we have taken the plates to be interradials, although with some hesitation, for they are not interbrachial, nor, strictly speaking, inter-ambulacral, but in part sub-ambulacral, and sub-tegminal. In their position they resemble the first interradials of *Platycrinus*, but the ambulacra of that genus rest against the edges of the plates, and only the covering pieces are exposed. In the Cyathocrinidæ, not only the ambulacral *plates*, but also the ambulacral *vessels* rest upon solid plates, and the small marginal plates on top of these plates sustain toward the side- and covering-pieces the same relation as the interradial plates of the Platycrinidæ toward their covering pieces.

The presence of three plates at the posterior side, as against one at the other four, would seem to indicate that they may be homologous with the first row of interbrachials of the Batocrinidæ; but upon closer examination it appears that the two structures are not exactly parallel. We have no doubt that also in *Cyathocrinus*, as in the case of *Batocrinus*, the posterior plate is broken up into two pieces by the middle plate; but this plate in *Cyathocrinus* is a madreporite, while that of *Batocrinus* is a supplementary anal. The former constitutes the *uppermost* plate of the posterior interradius, being separated from the first anal plate by the full length and depth of the sac; the plate of *Batocrinus*, however, which rests directly upon the anal, represents the *lowest* plate of the area.

Obscure also are the relations of the small marginal plates, which in *Cyathocrinus* overlie the larger ones, and which occur only at the four smaller sides of the disk, leaving the surface of the madreporite at the fifth side exposed to view. The only plausible explanation we can find for this structure is that these plates represent the higher disk plates, which for want of space overlapped, and gradually covered the larger ones; while those of the posterior side, instead of overlapping, were carried upward, and formed into a sac or tube.

The large interradial plates of the Cyathocrinidæ apparently have close affinities with the deltoids of the Blastoidea, and Carpenter and Bather* proposed to apply also to the plates of the former temporarily the term "deltoids." The plates of both groups rest upon the radials and support

* Ann. and Mag. Nat. Hist., 1892, p. 64.

the orals; but while those of the Cyathocrinidæ enclose a madreporite, those of the Blastoids enclose an anal piece. The conditions are thus not exactly alike, and we do not see why that term is any more appropriate than "interradials" — a term which has the advantage of being more general.

In the Hybocrinidæ the posterior side of the disk is less elevated than in the Cyathocrinidæ, rising but little above the level of the other four sides. The ambulacra are tegminal, and apparently rest upon the lateral margins of the four large interradial plates. There are no orals, the median portions of the disk being occupied by large covering pieces.

The ventral pavement of the Anomalocrinidæ, which we examined in a fine specimen from the Museum of Comparative Zoölogy, differs essentially from that of the two preceding families. It consists of rather large, moderately thick, irregular pieces, five or six deep, which decrease in size toward the centre and cover the peristome; no orals being distinguishable. The outer of these plates rest against the large incurved limbs of the radials, forming a wide and deep sinus for the reception of the ambulacra, which are on a lower level than the other disk plates, and in the Cambridge specimen of a different color, and thereby readily recognized.

The tegmen of the Poteriocrinidæ has never been found in perfect preservation. We hoped to find it by dissecting a number of finely preserved specimens, but the sacrifice was only rewarded by finding in a single instance a few small, scattered plates; from which we conclude that the covering was of very fragile construction. The form and size of their ventral sac is extremely variable; extending in some cases beyond the tips of the arms, in others consisting of merely a short cone. In some of the genera it is tubular, in others club-shaped; in some balloon-shaped; in some even spiral, the whorls of the coils either united or free; but in all cases, so far as we know, the plates are arranged in vertical rows, which sometimes diverge at intervals, and apparently in all of them the edges of the plates — not their substance — are perforated by pores or clefts.

A porous sac is also found in the Belemnocrinidæ, and probably exists in the Heterocrinidæ, but nothing is known of the other disk plates in these families.

In the Encrinidæ, according to Wagner,* the ventral disk rises to about the height of the second costals, where it contracts abruptly to one half its diameter at the base, and is surmounted by a small cone. The peripheral

* Zeitschr. d. Deutsch. Gesellsch., 1887, pp. 822 to 828.

part consists of small limestone particles, or irregular plates, and was evidently flexible; while the conical part, which is composed of larger pieces, appears to be almost rigid. Nothing is said about ambulacra, which were probably not visible in the specimen. That the cone represents a short ventral sac, and that the affinities of the Encrinidæ are with the Fistulata, and not with the Apiocrinidæ and other Neozoic Crinoids as heretofore, supposed by Miller, Müller, Zittel and Carpenter, is clearly shown from Wagner's description.

Among Apiocrinidæ de Loriol observed the tegmen in *Apiocrinus roissyanus*,* a species with large, massive plates interposed between the rays, and in which the plates of the cup gradually pass into the tegmen, which consists of rather heavy plates. The interbrachial plates were regarded by Carpenter as "calyx" interradials, *i. e.* homologous with the interbrachials of the Actinocrinidæ, the plates of the tegmen, however, as "disk" plates, — a position which was controverted by us.† We asserted that if those plates were "calyx" interradials, they should be followed by a "vault;" but if the tegmen was a disk, then the plates between the rays also had to be considered as disk plates. We came to this conclusion upon ascertaining that the plates of the tegmen form a continuation or extension of those in the cup. The plates of the two hemispheres in most cases pass imperceptibly from one into the other, and have the most intimate relations.

*Apiocrinus* is not the only Neocrinoid genus as to which there have been doubts respecting the homologies of the interbrachial plates. *Guettardicrinus* is morphologically in exactly the same condition, and the recent genus *Thaumatocrinus* has five large plates interposed between the radials, resting upon the basals, and followed by very minute, irregular pieces, which gradually pass into the tegmen. Also in many of the Ichthyocrinidæ the plates between the rays are large and heavy; while those of the tegmen are ill-formed and unusually small. *Glyptocrinus* has minute, irregular pieces in the tegmen, and well defined and regularly arranged plates in the cup. In all these cases Carpenter took the larger plates to be "calyx interradials," but called the others "disk plates," although the former occupy relatively the same position as the smaller ones, and as the disk plates of the Comatulæ, *Calamocrinus*, and the Pentacrinidæ. Our recent studies show plainly that neither the condition of these plates, nor the presence or absence of the ambulacra

* Paléont. Franç., 1re série; Anim. Invert., Crinoides, p. 272.
† Revision, Part III., pp. 63, 72, and 137.

in the tegmen, enables us to discriminate between perisomic and vault pieces; and this led us to inquire whether such a distinction actually exists in any group.

After it was demonstrated that the ventral surface of *Taxocrinus* is a true disk, we became convinced that our views respecting vault and disk would have to be modified as to other groups also, or be altogether abandoned. The latter was done in 1892, in a paper on "The Perisomic Plates," * in which we endeavored to show that the so-called "vault" of the older Crinoids is a modified disk. This interpretation has since been accepted by Agassiz, Carpenter, and Bather, who agree that the use of the term "vault" should be abandoned in a morphological sense. The modifications that took place are most apparent among the Camerata, in which there is a marked increase in the size and rigidity of the plates, which reached its culmination among Carboniferous forms.

The tegmen of Palæozoic Crinoids is often formed into ridges, which diverge from near the centre to the arm bases. These ridges, which are best defined, and occur most frequently, among Silurian Camerata, are formed either by covering pieces or the interambulacral plates. Such ridges also occur upon the disk of the Comatulæ, but they are formed exclusively by the ambulacral plates. Among the earlier forms ridges of this kind have been observed in *Actinocrinus quinquangularis*,† *Habrocrinus ornatus*,‡ *Marsupiocrinus depressus*,§ *Marsupiocrinus radiatus* (Plate VIII. Fig. 15); and *Platycrinus symmetricus* (Plate LXIX. Fig. 1*b*); in all of which the mouth is closed either by the orals, or in their absence by the uppermost covering pieces, which interlock with those of adjoining rays. Very prominent ridges occur also upon the disk of *Taxocrinus intermedius* (Plate III. Fig. 11), in which, contrary to the preceding forms, mouth and food grooves are opened out. The ventral structure of this species bears a remarkable resemblance to that of the young *Platycrinus symmetricus* (Plate LXIX. Fig. 1*c*); all that is required to convert the "vault" of this *Platycrinus* into a disk like *Taxocrinus*, is that its orals should be parted enough to let the ambulacra pass in to the centre between or over their edges. Its resemblance is equally striking to the recent *Calamocrinus* and *Hyocrinus*; a slight receding of the posterior oral and movable covering pieces would bring the three forms substantially into the same condition, all of which shows that the closure of the

* Proceed. Acad. Nat. Sci. Phila., pp. 345–375.

† Iconogr. Crin. Suec., Plate XVI. Fig. 28.

‡ Ibid., Plate XXVII. Fig. 5.

§ Ibid., Plate X. Fig. 16.

mouth in the older Crinoids is not accomplished by any additional set of plates, but by the plates which in recent Crinoids surround the mouth.

Cases in which the ambulacra enter the tegmen from beneath what were formerly called the interradial dome plates, are found in almost every family of the Camerata. They occur more frequently among genera in which the ventral surface is paved by small irregular pieces, such as *Glyptocrinus*, *Reteocrinus* and *Archæocrinus*; but also in others. A most instructive case of this kind is presented by a rather young specimen of *Megistocrinus nobilis* (Plate XLVII. Figs. 8*a*, *b*), in which not only covering pieces, but well defined side pieces enter the calyx. The ventral pavement consists of moderately large, irregularly arranged plates, which gradually decrease in size toward the arms. The tegmen is perfectly flat, except near its outer margin, where it is distinctly plicated to form the large openings for the ponderous arms. At the inner flat portions the ambulacra are concealed, but at the plicated outer part both covering- and side-pieces come to the surface, and are visible for some distance. It is now quite instructive that in another more adult specimen of the same species (Plate XLVII. Fig. 6) the parts of the ambulacra which in the former specimen were exposed, are roofed over from both sides by interambulacral plates of subsequent growth. This observation throws important light upon the development of the so-called vault of the Camerata generally. It shows that the same system of plates, which in a young specimen is in part *inter*-ambulacral only, may gradually become *supra*-ambulacral in another.

We find a somewhat different structure in a finely preserved adult specimen of *Megistocrinus Evansi* (Plate XLVII. Fig. 1*b*), in which in three of its rays two series of large, nodose, alternating plates pass out from near the orals in the direction of the ambulacra. The series are frequently interrupted by small, flat pieces, which are interspersed among the larger ones. In some places the arrangement of the larger plates, which are evidently covering pieces, is as regular as in any *Platycrinus*; but at others, owing to the interference of the smaller plates, quite irregular, especially in the two rays to the right of the anus, where scarcely any two of those plates are continuous. It is most remarkable that in no two specimens of this species is the arrangement of the covering pieces alike. In some of them, only the five large bifurcating plates, the so-called radial-dome pieces, are in view, followed by ten others of a second order. The ventral structure of this species not only offers a good proof that the so-called radial dome plates, as before suggested, are extravagantly developed covering pieces, but indicates that the "vault" was formed by a gradual extension of the interambulacral areas along the line of the ambulacra, either covering them entirely, or encroaching upon them and leaving the more prominent plates exposed.

In *Glyptocrinus* and *Reteocrinus* the tegmen is essentially in the same condition as in *Megistocrinus nobilis*, but no orals are distinguishable, and the whole ventral surface, including the median portions, is covered by minute granular pieces. The middle part is evenly convex, but toward the periphery there are ridges leading to the arm bases, and on top of these ridges the covering pieces are exposed. In the median portions the ambulacra were evidently subtegminal, being roofed over by superimposed inter-ambulacral plates, which form a continuous integument over them.

A careful study of the different tegmens which are found among the various families of the Camerata shows that the ambulacra, as a rule, are subtegminal in species with a high dome or bulging at the arm bases, but in species with a flat or depressed surface they are generally tegminal, or become tegminal before entering the arms. They are exposed in forms like "*Actinocrinus*" *quinquangularis*, *Habrocrinus ornatus*, *Marsupiocrinus depressus*, and *Glyptocrinus ornatus*, — species with a low disk; but they are necessarily subtegminal in genera such as *Cactocrinus*, *Siphonocrinus*, etc., in which the tegmen is high and conical. The condition of the ambulacra, therefore, whether tegminal or subtegminal, does not represent an essential structural feature, but is a natural consequence of differences in the form and construction of the tegmen in the respective species.

Now if it is true that a plated integument was formed in *Glyptocrinus* and *Megistocrinus* by the profuse development of the interambulacral plates, and their gradual fusion along the line of the ambulacra over a part of the disk, it would seem to follow that the more substantial vaults of *Actinocrinus*, *Batocrinus*, and *Physetocrinus* may have originated in a similar way, and that the body of these forms also was covered by a single set of plates. This seems to be confirmed by a very instructive specimen of *Physetocrinus*, in which the delicate structure at the inner floor is shown in excellent preservation (Plate V. Fig. 14). The specimen has the great advantage of being free from any silicious coating, such as obscured the structure in previous specimens of this kind. The outer surface of the tegmen is composed of moderately large, smooth pieces, of irregular form, closely fitted together at all sides. There are no orals, but near its outer margin there are radial dome plates of a first and second order, which are readily recognized by their large size and greater convexity. Other ambulacral plates are not visible. Examining the inner floor, we find the same arrangement of plates, and actually the same plates as at the outer side, but the general aspect is totally different. They look like sharply delineated stars, with as many rays as there are sides to the plates. There are abrupt depressions between the star-rays, which on meeting corresponding depressions of adjoining plates, form deep, sometimes cavernous pits, more or less undermining the plates, and which seem to have communicated with one another by imbedded passages all along the tegmen. The star-shaped plates extend over both the peristome and ambulacra, being occasionally interrupted by small, supplementary pieces, apparently solid. Thus the tegmen of *Physetocrinus* is not composed of two distinct sets of superimposed plates, as heretofore supposed, but of one set only, of which the plates are solid externally, and perforated or honeycombed throughout their inner portions. The presence of but one set is further confirmed by the position of the ambulacra, which follow the inner floor. This is of importance, for if the upper or solid part, as was supposed to be the case in the allied *Batocrinus* and *Actinocrinus*, represented a vault, and the inner part a disk, the ambulacra should lie between them; whereas in this case, lying below them both, they would be covered by two integuments, first by the overlapping interambulacral plates, and then by a vault, — an arrangement in the highest degree improbable. The ambulacral skeleton itself is not preserved in the specimen, but the place it occupied is clearly indicated by shallow grooves, formed by a thickening of the plates all along the interradial spaces.

The internal structure of *Physetocrinus* gives us the key to that of *Batocrinus*, *Dorycrinus*, *Actinocrinus*, *Teleiocrinus*, and of the Camerata generally, in all of which, as we no longer doubt, there is but a single integument; and the part which we have heretofore regarded as a disk forms a portion of the same set of plates, which are perforated at the inner floor so as to produce the numerous caverns and passages above described. These passages and pits may have served for the free circulation of water, and we think it highly probable that the older Crinoids had a very complex vascular water system, extending all the way from the interradial plates of the dorsal cup to the top of the ventral disk. This complex system was probably not required in recent Crinoids, in which many of the plates are perforated throughout, by means of which the surrounding water is brought in direct contact with any part of the body.

There are good reasons for believing that in the Camerata the water for respiration was introduced near the arm bases through small openings, described by us as respiratory pores, and then followed the canals and passages along the test. Such openings have been observed not only among the Actinocrinidæ and Batocrinidæ, but also among the Melocrinidæ and Rhodocrinidæ. In the genus *Dolatocrinus*, they are large and slit-like as in Ophiurids, in *Batocrinus* and *Actinocrinus* round, and in *Gilbertsocrinus* at the outer end of long tubes. The openings are always located between the rays and their main divisions, a little above the arm regions. Some species of *Dolatocrinus* have from four to six to each interradius, and two to four to each interdistichal space, all arranged horizontally. In *Dolatocrinus* this vascular system probably extended only over the peripheral portions of the disk, for the inner floor at the middle portion is perfectly smooth in the specimens. In *Batocrinus* and *Teleiocrinus* it probably extended to the outer margins of the orals (Plate V. Figs. 16 and 17); while in *Physetocrinus*, when the orals are unrepresented, it apparently occupied the whole tegmen.

We now come to the ventral structure of *Siphonocrinus*. It will be remembered that in *S. armosus* not only the ambulacra, but large portions of the anal tube, are subtegminal, and that the latter lies across the mouth and covers portions of the ambulacra. The tube, however, in two other species of this genus opens out centrally, thus showing that the subtegminal condition of the tube had no important bearing upon the general structure of the disk. As we understand the case, the anal tube, which is actually the outer end of the hind gut, in place of becoming free and piercing the central part of the disk as in the other two species, was roofed over in *S. armosus* by the interambulacral pieces in a somewhat similar manner to the calyx ambulacra of *Megistocrinus*.

Now if it is true that in forms like *Physetocrinus*, *Batocrinus*, *Actinocrinus*, and *Siphonocrinus*, there is no second integument, it may be considered as proved that a "vault," as an independent structure, did not exist in any of the Camerata, nor, in fact, in any of the other groups, and that the structure to which the term has been applied in these forms was evolved phylogenetically from the disk of the primitive types, of probably Pre-Silurian time.

The disk of the Fistulata also experienced notable changes in its palæontological development, but these took place on different lines. The plates of the tegmen at no time attained the rigidity and large size of that in the Camerata, nor did those of the dorsal cup, with the exception of the anal plates, undergo any material alterations. It was the ventral sac which gave to this group its characteristic feature. The sac in the earliest forms was quite small, but it soon attained such enormous dimensions that already in the Silurian it constituted the greater part of the calyx. At the close of the Carboniferous, however, it dwindled down almost as rapidly to its former insignificance, so that it is represented in *Cromyocrinus*, *Eupachycrinus*, *Erisocrinus*, and *Encrinus* by a very short cone. The respiration of the Fistulata was apparently directly through the test, but only at the posterior side of the calyx. It took place either by means of pores along the sac, or by a madreporite placed in front of the sac. The respiratory pores of the Fistulata only pierce the edges of the plates; while the water pores of recent Crinoids pass through the whole plate. The mode of respiration of the Larviformia is unknown. They had apparently no openings in the calyx except the anus, but they possessed pores along the arms at the sides of the covering pieces, which may have served respiratory purposes.

Most of the Ichthyocrinidæ have interbrachial plates, which in some species are large and massive, in others small; and some are regularly arranged, others irregularly. The mouth is opened out, the ambulacra are tegminal, and rest in an integument of very small, ill-formed pieces,* which extend to the interradial plates in the cup, and those at the sides of the brachial appendages. The small plates form pouches or sacs, which sometimes reach to the second or third bifurcation. The median lines of these pouches are occupied by the ambulacra, which converge to the mouth, separating the orals.

Here we have among Palæozoic Crinoids a tegmen, which has all the characteristics of the disk of living species, down to an uncovered mouth and open food grooves, thus demonstrating conclusively that the disk as a ventral structure is not confined to the Neocrinoidea. The discovery of this fact led to entirely new ideas touching the derivation of these groups. Before, it had been supposed that the "vault" ceased to exist in Neozoic times, or was reduced to the orals. It may now, we feel assured, be considered as established that the structure of the tegmen in the oldest Palæozoic Crinoids,

* We carefully removed the arms in several well preserved specimens of *Onychocrinus Ulrichi* and *O. diversus*, and in several instances found portions of the ventral disk imbedded in the dorsal cup, lying upon the inner floor of the plates. The disk of these species must have been extremely pliable, and probably consisted in part of soft tissues.

although the mouth in most of them remained closed throughout life, was not morphologically distinct from that of the Crinoids of existing forms, and that the so-called "vault" has been developed gradually from the disk. The Camerata, therefore, cannot be the progenitors of recent Crinoids; they represent a side group, which in the course of Palæozoic time departed essentially from the primitive type, reaching the culmination of extravagance in form and size in the Carboniferous, and becoming extinct at the close of that epoch.

### B. *The Anal Plates and the Anus.*

The Anal plates bear a most important part in the phylogeny of Palæozoic Crinoids, and are also of high importance in respect to classification. Some writers apply the term "anal plates" indiscriminately to all interradial plates of the posterior area, while others restrict it to the plates directly or indirectly connected with the anus. We apply the term to the latter plates, but only to such of them as take part in the dorsal cup; the others being plates of the anal tube or ventral sac.

The anal plates in all Camerata, when present, occupy the median line of the posterior area, so as to divide the interbrachial plates into two equal sets; and in rows containing an odd number they have the effect, as it were, of breaking up the middle plate into two, even in cases where no anal plate is inserted between the segments. The latter is the case in the Actinocrinidæ, in which the first interbrachial row at the posterior side always consists of two plates, in place of one as in each of the others; though all have an anal plate between the radials, and an extra plate in the second interbrachial row. In the Batocrinidæ and Thysanocrinidæ there are two interbrachial pieces above the first anal, which enclose a second anal piece. The Hexacrinidæ have but one large anal plate resting upon the basals. The Eucalyptocrinidæ have no anal plate at all, the five interbrachial areas being perfectly symmetrical. Such is the case also in *Dolatocrinus*, *Stereocrinus*, *Centrocrinus*, *Allocrinus*, and *Patelliocrinus;* while the typical Melocrinidæ have an anal plate in one or more of the upper rows. Similar variations occur among the Rhodocrinidæ, in which anal plates may be either present or absent. The Platycrinidæ have no special anal piece, but the middle plate of the proximal row at the posterior side is considerably enlarged, and evidently united the functions of an anal plate with those of the regular interradial.

It thus appears that the anal plates vary considerably in their position and distribution, and in some groups are absent altogether. As a general rule, they are largely represented in species with a strong tube, or a protruding lateral opening; while in forms in which the anus is central, as in the Eucalyptocrinidæ, or comparatively small, they are either wanting or but feebly represented. The anus, although more or less influencing the whole posterior area, did not necessarily require the introduction of anal plates, and when the tube was small, an enlargement of the regular interbrachial plate sufficiently increased the width of the area. The anal plates, therefore, do not appear to constitute an essential element of the Crinoids, but seem to be supplementary pieces, introduced when the space was insufficient to accommodate the tube.

Among the Fistulata, the term "anal plates" has been applied to two plates of different origin, the one radial, and the other interradial. The latter is the homologue of the "special" or "first" anal plate of the Camerata, and rests upon the truncated posterior basal. When there are two plates in the species, as in most of the Poteriocrinidæ, and occasionally in other families, the second — which is actually the first or lowest in point of position — is located obliquely to the right of the first, so as to encroach more or less upon the proximal face of the right posterior radial. Its lower angle rests upon the upper sloping faces of the adjoining basal, its upper face supporting the first plate of the tube, which in some of these genera is partly enclosed in the calyx. To understand the position of the lower plate, it should be noted that throughout the modifications which took place in the posterior interradius in geological time, this plate always retained its alternate arrangement with the basals, and occupied a radial position from the beginning. Its form was changed, and to some extent its relation to surrounding plates, by the increasing width of the ventral sac, which caused a displacement of the arm-bearing plates. The oblique position which the plate holds toward the posterior basal and the regular anal plate, and the latter toward the first plate of the tube, gives to these pieces a sort of alternate arrangement, which is continued throughout the tube.

The changes that took place among the anal plates in the various groups of the Fistulata have been discussed by us at different times,* from which it appears our views have undergone considerable modification as the result of

* 1879, Revision, Part I., pp. 71 and 72; 1883, Amer. Journ. Sci., Vol. XXVI., pp. 365 to 377; 1885, Rev. Pt. III., Sect. I., pp. 11, 12, 40; and 1886, ibid., Sect. II., pp. 196 and 210.

further research. The subject was also discussed by Dr. P. H. Carpenter in his paper "On the Relations of *Hybocrinus*, *Baerocrinus* and *Hybocystites*,* and lately by Mr. F. A. Bather in a paper "On the British Fossil Crinoids."† Bather agrees with us and with Carpenter that the radially disposed plate is a posterior inferradial, which in some groups took on anal functions. He gave it the name "radianal," which we have accepted, but we apply the term only when the plate actually serves as a support of the tube. Respecting the origin of the other plate, which we take to be a special interradial, he advances views from which we regret to be obliged to dissent. His idea is that this plate "originated as a plate morphologically corresponding to an ordinary brachial," and he undertakes to prove that in its palæontological development it passed down from above the radials to the basals, and between the radials. He calls it a "brachianal," — a term which becomes meaningless if it proves to be interradially disposed. To this plate we apply the general term "anal plate," as we take it to be the homologue of the anal plate of the *Antedon* larva, and structurally identical with the first anal plate of *Actinocrinus*.

We give, on Table C, a series of diagrams to illustrate the development of the anal plates, in which the "brachianal"—of Bather — is marked $x$. The radials are designated by the letter $R$, and when compound, the lower section — the inferradial, which is also the "radianal" when it helps to support the tube — by $R'$. The tube plates are called $t$.

To the Plate $R'$ we have already alluded in the chapter on the radials, discussing those forms in which it represents a part of the radial, and lies in a vertical line with $R$. Let us now consider those forms in which it serves as anal plate. Among these forms, of which *Poteriocrinus* may be regarded as the type, four of the five radials are simple, and the Plate $x$, which is generally represented, rests upon the basals. The ventral sac, which in the earlier forms was rather insignificant, had rapidly increased in size at the close of the lower Silurian, in such a manner that the sloping upper faces of the radials were insufficient to support it, and certain changes in the structure of the dorsal cup became inevitable. It thus happened that the two posterior radials, which had previously been in contact laterally (*Iocrinus*, Fig. 9) were now parted, and the Plate $x$ was introduced to fill the vacant space (*Dendrocrinus*, Fig. 13). These modifications, however, did not affect the position

* Quart. Journ. Geol. Soc. London, Vol. XXXVIII., pp. 298–312.

† Ann. and Mag. Nat. Hist. (6th Ser.), Vol. V., April, 1890, pp. 319 to 334.

of the inferradial, which retained its place between the upper sloping faces of two basals, only changing its outlines to conform to the shape of, and fit in between, adjoining plates. In the Carboniferous, in which the ventral sac attained its greatest dimensions, and the lower faces of the costals frequently fill up the whole width of the radials, leaving no space upon their distal faces for an attachment of the tube, the superradial, *R*, was shifted to the right, into a position almost directly above the right postero-lateral basal, and obliquely against the inferradial *R′* (*Poteriocrinus*, Fig. 2). Finally toward the close of the Carboniferous, when the tube was reduced to its primitive insignificance, the anal plates gradually disappeared, and the five radials resumed their normal position as in *Erisocrinus*, *Stemmatocrinus*, and *Encrinus*.

This is entirely different from the interpretation of Mr. Bather, who reaches the conclusion that the anal plate *x* was primitively derived from a brachial, and that in geological time it passed down from above into the dorsal cup. He regards (*op. cit.*, p. 329) "those forms as primitive in which the radianal is more of a radial and less of an anal, in which it is not in an asymmetrical position but corresponds to the other lower brachial plates. Such forms are *Iocrinus*, *Heterocrinus*, *Ectenocrinus*, *Anomalocrinus*, and *Merocrinus*. Now in all these forms *x* is supported by *R*, and does not touch *R′*. Obviously then *x* is not derived from *R′*, but originates above *R*, and on its left side. By parity of reasoning we assume the next stage to be represented in such forms as *Hybocrinus* (?), *Ottawacrinus*, *Dendrocrinus*, and *Homocrinus*, since in them *R′* is rather more asymmetrical. In these *x* has passed down from above *R*, and now rests with its lower half between the right and left posterior radials, being supported partly by *R′* and partly by the basal. *Caraboerinus*, *Botryocrinus*, and similar forms are, as all acknowledge, the next stages in the shifting of the radianal; in these *x* has sunk still lower into the dorsal cup, and is now entirely in a line with the radials. . . . In *Parisocrinus* and *Euspirocrinus* among pinnuless forms, and in the Poteriocrinites, another change has taken place; the radianal has passed through a revolution of 90°, and the lowest plate of the ventral sac (*t*) has sunk down between *R* and *x*."

Before inquiring into the validity of this argument, it will be well to ascertain whether the plates of the different genera which Bather calls *x* are structurally the same thing, for an error in this respect would be fatal to the whole theory. The question is, is his plate *x* in *Iocrinus* and *Merocrinus*, which rests upon the one marked by him *R* or *C*, and that resting upon *R′*

in *Hybocrinus*, and $R$ in *Anomalocrinus*, homologous with the plate of *Dendrocrinus, Homocrinus*, etc., which is supported by $R'$ and partly by the basals, and also with the plate of *Poteriocrinus*, which rests upon the basals and against the radianal $R'$? This question was not discussed by Bather, though we had expressed views different from his respecting the plate $x$ in *Iocrinus* and *Merocrinus*. That plate was regarded by us, in both genera (in *Iocrinus* as early as 1879),* as a plate of the tube, and, so far as we know, we never made any statement from which he might infer that we thought it represented the plate $x$; yet he quotes us in his diagrams as if we had done so in 1879.

Instead of commencing with the earliest forms, as Bather did, we begin with the simplest, and select as a starting point the genus *Cyathocrinus*, which is so well known to every palæontologist. *Cyathocrinus* has simple radials, and but one anal plate, which, as all writers agree, represents the plate $x$. It rests upon the truncated upper face of the posterior basal, between two radials, and is generally followed by three plates of the tube (Fig. 3), of which, as in the Batocrinidæ, the two at the sides rest to an equal extent against — or rather upon — the sloping upper faces of adjoining radials. The structure of *Graphiocrinus* de Kon. and Le Hon, as amended by us in 1879, is similar to that of *Cyathocrinus*. This genus also has only the plate $x$ represented, but here it is angular at the upper end instead of truncated, and supports but two equal plates of the tube. This produces a sort of bilateral symmetry in the posterior side of the tube, each plate supporting a vertical row of hexagonal or subquadrangular pieces.

Next in order we take *Dendrocrinus*, in which the right posterior radial is compound, and its two plates are in line vertically. This genus is an intermediate form between the earlier and later Fistulata, and its structure throws important light upon the phylogeny of the group, especially as to the anal plates. Contrary to the rule in most of the earlier Fistulata, the plate $x$ is well represented, but the inferradial, $R'$, is not in a position to perform anal functions.

Let us examine the form represented by *Dendrocrinus Casei*, from the Lower Silurian of America (Fig. 13), a species with rather narrow, horseshoe shaped radial facets, and an extremely large ventral sac. The two posterior radials are widely separated, and the plate $x$ is succeeded, as in *Cyathocrinus*, by three plates, $t$, $t$, $t$, of which the middle one rests upon the

* Revision, Pt. I., p. 65.

truncate upper face of plate $x$. The plate to the right lies at a somewhat higher level than the one to the left, and does not touch $x$, owing to the greater length of the compound radial, while that to the left touches it slightly. The three plates form part of the free tube, and each one is followed by a vertical row of other tube plates.

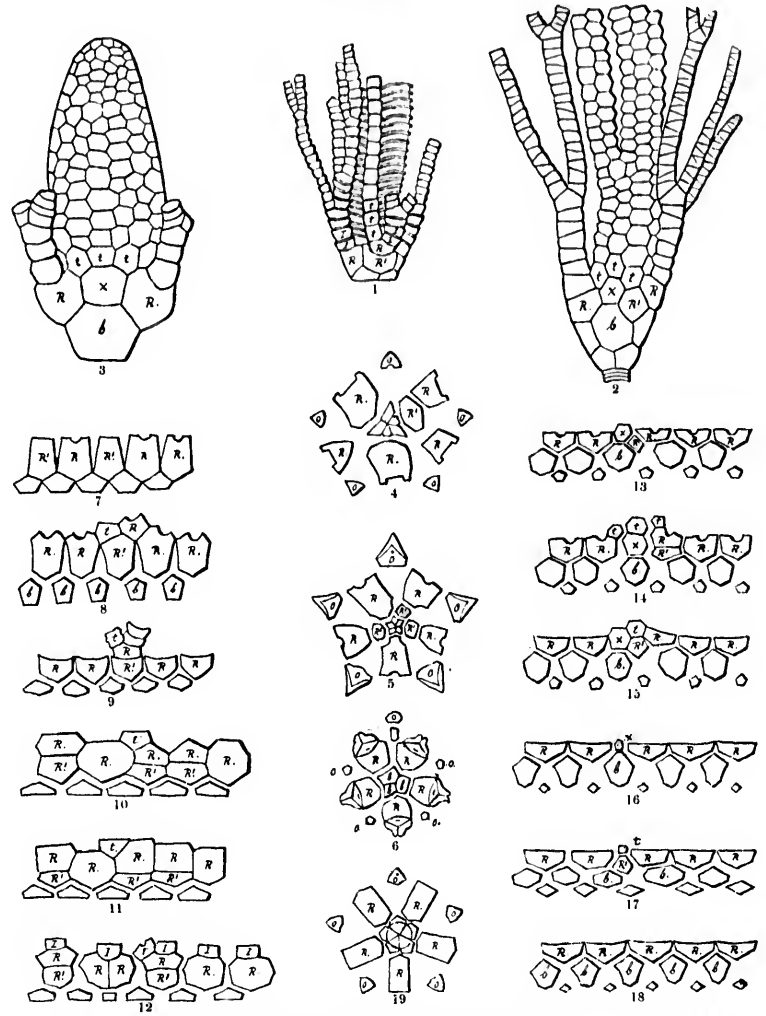
Comparing this structure with that of *Heterocrinus* (Fig. 10), *Ectenocrinus* (Fig. 11), and *Hybocrinus* (Fig. 8), we find that the plate $t$ in all these forms takes practically the place of the three plates ($t\,t\,t$) in *Dendrocrinus*. In either case the plates constitute the lower tube plates, and rest — the one as well as the three — upon the sloping upper faces of the two posterior radials; but while the three plates of *Dendrocrinus* are supported by a special anal plate, the radials of *Heterocrinus, etc.*, meet underneath, and the anal is unrepresented. In *Dendrocrinus*, which has an extremely large anal tube, the anal $x$ is well represented; while in the three other genera, in which the tube is narrow, and the outer edges of the radials are sufficient to support it, that plate is wanting. If it were true that the plate $t$ in *Heterocrinus* represents the plate $x$, and sunk down in palæozoic times to the basals, as supposed by Bather, the plate $x$ would be represented twice in *Dendrocrinus Casei*, once by $x$, and again by $t$, both plates being present and in place.

Bather makes the statement (p. 331) that the "brachianal" and the plates succeeding it in regular series, are to be regarded as brachials, but that the remaining plates of the sac are nothing more than plates deposited in an extension of the ventral perisome, and in conformity with this he has called the superradial of *Iocrinus* an axillary plate. The term "axillary" in Crinoid terminology is given exclusively to plates of the rays, and every axillary is followed necessarily by a branching of the arm. Bather in using that term must have supposed that the so-called brachianal, and the plates succeeding it, are parts of a modified arm, which in geological time became incorporated into the sac, for in no other way could we understand why he called it an axillary. He has probably been misled by the angularity which occurs upon the upper face of the superradial, or by the form of the plates succeeding it to the left, and the slanting position of the posterior arm to the right. In that case he overlooked that the radials in *Actinocrinus* also have sloping upper faces, and yet that those plates are not axillaries, supporting as they do at one side a costal, but an interbrachial at the opposite side; and it did not occur to him that such might be the case also in *Iocrinus*. Examining the anal interradius as it appears in the Camerata among the various families, we find in the Batocrinidæ directly above the plate $x$ a supplementary anal, and an interbrachial at each side of it, exactly as in most species of *Cyathocrinus* and *Dendrocrinus*, except that the interbrachials of the two latter — *i. e.*, the plates corresponding to them — are incorporated into the tube, but those of the Batocrinidæ into the cup. Turning to the Actinocrinidæ, the plate $x$ supports a supplementary anal in the second interbrachial row, but none in the first, a structure recurring in *Graphiocrinus*, in which $x$ is followed by two tube plates which take the place of the two interbrachials of *Actinocrinus*. In the Dolatocrinites, however, in which $x$ is wanting, and the first row of the anal interradius is formed of a single plate, this rests upon the sloping faces of two radials, thus occupying almost the same position as the plate $t$ ($x$ of Bather) in *Ectenocrinus*, *Hybocrinus*, and *Iocrinus*. That the plate $t$ in some of these forms is somewhat irregular in position, leaning more to the right than to the left, is due to the asymmetry of the right posterior radial.

From these observations it appears that there is a close agreement between the anal plate and tube plates of the Fistulata on one side, and the anal plate and interbrachials in the cup of the Camerata on the other; and we are led to believe that those plates respectively are homologous. Admitting this, we have a much more satisfactory explanation of the anal plates of the Fistulata than that given by Bather, whose views are totally at variance with the structure of the Camerata, and are based upon premises which are, to say the least, hypothetical.

After agreeing upon the structure of *Dendrocrinus* and *Iocrinus*, that of the other Fistulata is readily understood. *Anomalocrinus* is in a condition similar to that of *Iocrinus*, but it has two compound radials instead of one (Fig. 12). The plate $x$ is unrepresented, and the tube, which is narrow, rests within a notch formed by the sloping upper faces of the two posterior radials. Nearly the same structure is found in *Heterocrinus* and *Ectenocrinus* with three compound radials, and in *Hybocrinus* with but one, and in all of them the plate $x$ is wanting. How Mr. Bather could conclude from the structure of *Ectenocrinus*, *Iocrinus* or *Hybocrinus*, three of the most primitive forms, that $x$ originated as a plate "morphologically corresponding to an ordinary brachial," and that $t$ could sink down to the basals, we do not understand. It appears from his own diagram that the plate which he calls $x$ in *Ectenocrinus* is placed symmetrically between the two posterior radials, resting as much on the one plate as on the other, but not touching the basals.

## TABLE C.



DIAGRAMS ILLUSTRATING THE CHANGES IN THE DEVELOPMENT OF THE ANAL SIDE IN THE INADUNATA.

1. *Iocrinus subcrassus;* 2. *Poteriocrinus;* 3. *Cyathocrinus;* 4 *Pisocrinus;* 5. *Haplocrinus clio;* 6. *Symbathocrinus;* 7. *Bacrocrinus;* 8. *Hybocrinus;* 9. *Iocrinus;* 10. *Heterocrinus bellevillensis;* 11. *Ectenocrinus;* 12. *Anomalocrinus;* 13. *Homocrinus;* 14. *Dendrocrinus;* 15. *Poteriocrinus;* 16. *Ceriocrinus;* 17. *Ulocrinus;* 18. *Erisocrinus;* 19. *Allagecrinus.*

*b* = basals; *R* = radials; *R′* = inferradial; $x$ = speceial anal plate; *I* = costals; *t* = tubeplates; *o* = orals.

See our diagram (Fig. 11). So also the plate *t* of *Heterocrinus bellevillensis* (Fig. 10), though less symmetrically disposed, rests upon both radials, and not on the plate to the right only, as figured by Bather.

We now pass to those forms in which the inferradial *R′* performs the functions of an anal plate. The first step in this direction is shown by *Homocrinus* (Fig. 14), *Botryocrinus*, *Oncocrinus*, and *Barycrinus*, in which the superradial *R* has shifted slightly to the right, and is connected with the inferradial by an oblique suture; contrary to the case of *Dendrocrinus*, in which the two plates are arranged vertically (Fig. 13). The plate *t* in those forms rests upon *R* without touching *R′*, and the plate *x*, which is comparatively large, rests against both sections of the compound radial.

Bather explains the evolution that took place in these forms by "the shifting of the radianal," and that "*x* has sunk still lower into the dorsal cup, and is now on a line with the radials." Nothing of this kind is indicated by the specimens, which clearly show that the radianal throughout the Fistulata retains the same position, whether it constitutes a part of the radial or serves as anal plate. It only changes its outlines so as to conform to the shape of contiguous plates. As the tube became larger, the radials spread out, and the vacant space thus formed was filled by a new plate, *x*. There was no sinking of the plate *t*, which never moved from its place *above* the radials.

Another stage in the developmental history of the anal area among the Fistulata is presented by *Parisocrinus*, *Atelestocrinus*, *Euspirocrinus*, and the typical Poteriocrinidæ. Bather, in alluding to them, makes the following statement: "In the Poteriocrinites (see our diagram Fig. 2) another change has taken place; the radianal has passed through a revolution of 90°, and the lowest plate of the ventral sac (*t*) has sunk down between *R* and *x*." If we understand what this means, he assumes that the lower section of the radial moved to the left; while in fact, as the specimens show, it was the upper section of the plate that moved away, shifting to the right and leaving a space for *R′* and *t* to meet. Thus it was that *x* came to rest against *R′*, but not against *R*, from which it was separated by the plate *t*. An increase of width in the anal area became necessary, as the surface for the support of the tube was insufficient to hold it. In *Homocrinus* and *Dendrocrinus*, the costals occupy only a comparatively small part of the radial, and a rather large portion of the latter serves as a support for the tube. In the Poteriocrinidæ, however, and in *Parisocrinus*, *Euspirocrinus*, and *Atelestocrinus*, in which the brachials fill up the greater part, or all of the distal face of the radials, it required additional surfaces for the accommodation of the large tube.

From the structure of the typical Poteriocrinidæ we come to that of *Ulocrinus*, *Graphiocrinus*, *Ceriocrinus*, *Erisocrinus*, and *Stemmatocrinus*, which we regard as transition forms toward *Encrinus*. The ventral tube, which in the latter of these forms dwindled to a short cone, did not require as large a support in the dorsal cup, and as the anal plates gradually became obsolete, the posterior radials resumed a symmetrical form. In *Ulocrinus* (Fig. 17) the plate *x* was crowded out by the large radianal; while in *Graphiocrinus* and *Ceriocrinus* (Fig. 16) only the former is represented. In *Graphiocrinus*, with a wide ventral sac, the anal plate is large; in *Ceriocrinus* it is reduced to a small piece, and the posterior basal is considerably elongated. *Erisocrinus* (Fig. 18), *Stemmatocrinus*, and *Encrinus* have no anal plates at all, the cup being perfectly symmetrical; and the tube rests entirely upon the edges of the radials, whence it started in *Hybocrinus*, *Ectenocrinus*, and allied forms.

In view of these facts, it seems to us that Bather's theory of a "brachianal" is based upon a wrong interpretation of some of the plates. If it were true that the plate of *Iocrinus* to the left of the supraradial passed down in later forms to the basals, it would mean nothing less than a partial revolution of the entire tube. This, however, is disproved by the structure as well as the palæontological development of the tube, which latter is generally composed of longitudinal rows of hexangular pieces, alternating in adjoining rows. In the earlier and simpler forms the tube consists of only five series, one to each interradius, that of the anal side resting upon plate *t*. Later on, as the tube grew larger, a new row of plates was introduced with plate *x* supporting it. When there are three series, as in *Dendrocrinus*, the third generally rests upon one side of the left posterior radial. The arrangement of the plates within the rows is so regular that if a sinking of the plate *t* had taken place, it would certainly be indicated by some disturbance among the lower plates in the tube. In species where the tube has more than three rows, one or more of the primary rows dichotomize at some distance from the cup. The fact that the increase of the tube phylogenetically took place by the introduction of new rows of plates, is a strong argument in favor of our idea that the plate *x* is also a supplementary piece, and was introduced in the same manner as the plates which it supports.

The symmetry of the Crinoids, as a rule, is bilateral, and the anal area occupies the median axis. The asymmetry which occurs in many Fistulata, and in certain Ichthyocrinidæ, is caused by irregularities in the radials. Wherever these attain a regular form, the plate *x* takes its median position, and the plates of the ventral tube are arranged on a strictly bilateral plan.

Whether the symmetrical calyx, as represented in the Silurian and later Cyathocrinidæ, was evolved from the asymmetrical form, we are unable to ascertain. It may be that the two had a common symmetrical ancestor, or that all these Crinoids were primitively asymmetrical, and that the lower section of the posterior radial became early resorbed in some cases. Against the former theory it may be said that in the Lower Silurian Fistulata, so far as we know without exception, the right posterior radial is compound, and that the symmetrical form occurs with the other in the same families; against the latter, that the symmetrical form is already well represented in the Upper Silurian.

We have made no reference here to the Calceocrinidæ and Catillocrinidæ, as we have not at present the material to study the older forms; but we feel quite certain that their structure in this respect shows no material departure from that of the older Fistulata.

The anus of the Crinoids is located in the disk, and is either central, subcentral, or marginal, — in the latter case sometimes coming down to the arm region. In some species there is merely a simple opening passing out directly through the disk; others have a tube with an opening at the distal end or along the side. The size of the tube is quite variable. In some genera it rises to a height of several inches beyond the arms; while in others it is less than half their length. The tube is composed of heavy, generally nodose, wedgeform pieces, admitting but little mobility in the structure. When there is no tube, the anus is generally situated within the centre of a wart-like inflation, composed of very minute pieces, which possibly were movable, and could be drawn in by the animal, like those in the "proboscis" of recent Crinoids, so as to open or close the aperture.

There has been some difference of opinion whether or not species with an anal tube should be separated generically from those with a simple opening. Considering the slight differences upon which many genera have been founded, it would seem that the tubular structure ought to be of sufficient importance to justify a separation; but considering that various groups, after being carefully restricted with reference to all other characters, include both forms, its value as a full generic character might well be doubted. It was probably this that led Meek and Worthen to establish subgenera for these forms. We finally concluded to make them full genera, finding considerable objection among naturalists to subgeneric divisions. Only in *Platycrinus* and *Melocrinus* were we obliged to retain both forms under the same generic name, as we are unable to separate them. Their tegmens are rarely preserved, and among the species of *Platycrinus* especially are found all possible gradations from a simple opening to a good sized tube.

As a rule, a tube occurs more frequently among species in which the arms form a continuous series around the calyx; while species in which they are arranged in clusters often have a simple opening. Most of the latter forms have a wide, more or less depressed space along the disk, between the two posterior rays, for the fœcal matter to pass out; but when the tube is long, and the arms in close contact all around, the excretions were discharged above the arms.

Occasionally, among species with a slender tube, we find specimens in which during the life of the animal the tube was broken at the base, and the fractured edges upon the disk were rounded off by calcareous growth, so that it appears like a simple opening. From this we conclude that the tube had no important bearing upon the general organization of the animal, and that the Crinoid could live without it. This is also indicated by specimens in which the anal tube was obstructed, and a new passage formed at another place. Abnormal passages of this kind occur along the tube, upon the disk, within the dorsal cup, and even within the basal ring. They are more or less restricted to the posterior side, but are not necessarily in a vertical line with the anus, as we formerly supposed. When it occurs within the basal ring, the opening is located anteriorly, but turns to the right whenever it enters the sides of the dorsal cup. It is located posteriorly — or nearly so — close to the arm bases, but above the calyx it may occur on any side of the tube. The Museum of Comparative Zoölogy has a very interesting specimen of *Batocrinus longirostris*, in which a new tube of the same size as the original one has been formed just above the calyx. In this instance apparently the second tube also became obstructed, and a third one was in process of formation. A similar case is presented by our specimen of *Batocrinus laura* (Plate IV., Fig. 14). The tube in the specimen of *Eutrochocrinus Christyi* (Plate IV., Fig. 16) gives off a small branch horizontally at a short distance from the disk. In another specimen of that species (Plate IV. Fig. 17), in which the tube is broken above the arms, it was replaced by another, which starts off somewhat obliquely from the top of the stump. A tube in a similar condition was observed in a specimen of *Lobocrinus pyriformis*, but there the recuperation made but little progress, for the new part did not attain one third the width of the old tube at the point of fracture. In the specimen of *Macrocrinus jucundus* (Plate IV. Fig. 15), a small branch starts from the tube close to the calyx, while in another specimen of our collection a branchlet is given off near the end of the tube. In Fig. 12 of the same plate (*Steganocrinus pentagonus*), and in Fig. 11 (*Teleiocrinus umbrosus*) a second tube was formed at the top of the disk, in the former occupying the median line of the posterior area, and in the latter directed slightly to the right. In the remarkable specimen of *Eutrochocrinus Christyi* (Plate IV. Fig. 13) all the arms of the right posterior ray, and the outer arm of both adjoining rays, were destroyed, and the break in the test was closed by irregular new plates, which support a conspicuous second tube. A still more remarkable instance of recuperation is presented by a specimen of *Batocrinus subæqualis* (Plate IV. Fig. 10), in which an enormous tube breaks forth above the basals. It occupies the whole length of the dorsal cup, and involves the plates of the posterior interradius, as well as of the posterior ray, and even some of the arm openings. The plates bulge outward almost at right angles to the sides of the cup, and form the lower part of the tube. Fig. 9 has a very large opening between the basals leaning somewhat toward the anterior side, which we think performed the functions of the anus in that specimen.

Passing now to the Inadunata Larviformia, it must be stated that, so far as observed, the anal $x$ is unrepresented throughout this group (see Figs. 4, 5, 6, and 19 of the preceding diagrams), and we know of no case in which the anal tube, where it exists, is supported by an inferradial. This is explained by the absence of interbrachial and interambulacral plates, and the position of the anus intermediate between the radials and orals, or piercing the latter. *Pisocrinus*,* *Phimocrinus*, and *Symbathocrinus* have a long slender tube be-

* The tube of *Pisocrinus* was observed by Bather, and described by him in his late work on "The Crinoidea of Gotland," Part I. p. 22). It rests upon the truncated limbs of the compound radial and the large simple one to the left; but not upon the two supported by the plate $R'$. Bather refers the proximal plate of the tube to the anal $x$, although the plate rests, like $t$ in *Ectenocrinus* and *Hybocrinus*, upon the radials, and takes no part in the composition of the cup. So also the corresponding plate in *Symbathocrinus* is a tube plate, and not an anal as we stated in our earlier writings.

tween the arms to their full length, which in *Symbathocrinus* is composed of elongate quadrangular pieces. The tube rests upon the upper faces of the posterior radials, and extends to the tips of the arms. *Haplocrinus*, as we understand it, has a simple anal opening, piercing the upper half of the posterior oral. *Cupressocrinus* has a well-defined aperture between the muscle plates of two adjoining radials.

The anus of the Inadunata Fistulata has been observed in but a few instances, and then only in the Cyathocrinidæ, the Poteriocrinidæ, and in the embryonic *Hybocrinus* and *Carabocrinus*. In all of these cases, the opening was apparently covered by a rather large, rounded pyramid of eight or more pieces, which resembles the anal pyramid in the Cystids. In *Carabocrinus*, in which the ventral disk remains permanently in the larval state,

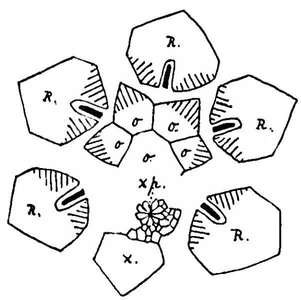



FIG. 1.

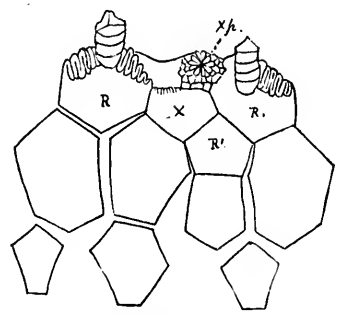



FIG. 2.

*Carabocrinus.* — Fig. 1. Ventral aspect. Fig. 2. Dorsal aspect.
$R$ = radials; $R'$ = radianal; $x$ = anal; $xp$ = anal pyramid; $o$ = orals.

having five large orals similar to those of the Larviformia, and subtegminal ambulacra, the pyramid is excentric and directed upwards (Figs. 1 and 2 of the accompanying diagrams).* A similar anus was observed by W. R. Billings in *Hybocrinus conicus*. In *Cyathocrinus* we have observed the anal pyramid in several species, and found it located in all of them at the end of the tube, directed anteriorly (Plate VII. Figs. 11 *ab* and 12 *ab*). The anus of the Poteriocrinidæ, which we have seen in *Poteriocrinus*, *Decadocrinus*, and in several species of *Scytalocrinus* and *Scaphiocrinus*, is located at some distance from the top of the ventral sac, and invariably at the anterior side, sometimes

* These diagrams were made after drawings by Mr. Walter R. Billings. The specimen of Fig. 1 is in the collection of Mr. J. Stewart, that of Fig. 2 in his own collection.

very low down in the sac (Plate VII. Fig. 1 *a*). An anal pyramid has never been found in place in this family, but that it existed, at least in some of the species, seems very probable from the form and large size of the opening (Plate VII. Figs. 1 *a*, 2 *a*, *b*, 3, 4, 7, 8). There are other Poteriocrinidæ, and especially among species with an inflated, balloon-shaped sac, which have no openings in the sac, and we are inclined to suppose that in these cases, and also in many other Fistulata, the anus was located in the disk proper between the sac and the mouth. In the remarkable *Aulocrinus* represented on Plate VII. Fig. 9, there is a large spout-like tube passing out from the huge sac between the arms on the anterior side, half way down, like the simple opening in Figs. 7 and 8. We have found this extraordinary tube preserved in five other specimens of this species, and its form and position are very constant.

The anus of the Ichthyocrinidæ has been observed only in *Taxocrinus* and *Onychocrinus* (*Forbesiocrinus* de Kon. and Le Hon). Both genera have a small tube, of which the posterior side consists of a vertical row of subquadrangular, comparatively large plates. Its anterior side is composed of a large number of very minute pieces, forming a kind of pouch, widest at the proximal end, which gradually passes into the disk. At the anterior side the tube leans considerably to the right, and it may be suggested from this that *Taxocrinus* and *Onychocrinus* are derived from the asymmetrical *Gnorimocrinus*, which apparently had a similar tube. The arrangement of the anal plates in the Ichthyocrinidæ is substantially the same as in the Fistulata. In some of their genera only the plate $x$ is represented, in others $R'$; while still others have no anal plate at all. Bather makes no reference to the anal plates of the Ichthyocrinidæ, but regards the anals of the Camerata as morphologically distinct from those of the Fistulata. On page 319 (*op. cit.*) he says: "it may be pointed out that, as interradials do not enter into the composition of the dorsal cup in any Fistulata, none of these plates can well be the homologues of interradials: in many of the Camerata actual interradials are present in the anal area, but in the Fistulata at least we must look elsewhere for the origin of the so-called 'anal' plates." Now if it is true that the anals of the Camerata represent something different from those of the Fistulata, because they possess no interbrachials, it must be the same also with the anals of the Ichthyocrinidæ, among which interbrachials are represented. But what would be the result? Some of their genera have interbrachial plates, and others not. In *Lecanocrinus Billingsi** there is at the posterior side an anal $x$, together with a radianal; while at the other four sides the radials and costals of adjoining rays meet laterally. *Lecanocrinus macropetalus* Angelin (not Hall),† on the other hand, with exactly the same arrangement of anal plates, has a large interbrachial plate at the four regular sides. The case is even more perplexing in *Taxocrinus Thiemei*, of which some specimens have one or three interbrachials, while others have none. We thus find within the same genus, and even within the limits of the same species, interbrachials present or absent, and according to Bather's theory the anal plates of one specimen would be homologous with the anals of the Fistulata, and those of the other structurally distinct. He seems to have regarded the anal plate in the larva of *Antedon* as the homologue of the plate $x$ in the Fistulata, because the genus has no interbrachials. He says: "it is not an interradial; for the so-called 'interradials' that some observers claim to have seen are only perisomic plates of no morphological importance; further it is a most gratuitous assumption to make *Antedon* the only form with an interradial in the anal area, while devoid of true interradials in the other interradii." In assuming that *Antedon* has no interradials, he employs the term in the narrow sense in which it has been used heretofore; but since then we have learned that all plates interposed between the rays and the ambulacra constitute parts of the same element, and the same plates morphologically may be interbrachial in one group, and partly or wholly interambulacral in another.

*Thaumatocrinus* is the only recent genus which has a tube, such as we find among the Palæocrinoidea. This tube rests upon a large interradial plate, which, however, is not a special anal, for a similar plate is interposed between the radials of the other four sides, exactly as in the Rhodocrinidæ. This seems to us a further proof that the plate $x$ is not a primary element, but a supplementary plate, and was introduced only in cases where the structure of the anus required it.

* Iconogr. Crin Suec., Pl. XXII. Fig. 25.
† Ibid., Pl. XIX. Fig. 4

## INTERNAL CAVITY OF THE CALYX.

### A. *The Chambered Organ and the Axial Canals.*

A striking feature in the organization of the Comatulæ is the quinquelocular organ, situated in the cavity of the centrodorsal, and placed at right angles with the central axis. This organ was first noticed by Heusinger, who in 1828 described it as the central organ of the blood vascular system. Müller also took it to be a heart-like organ in connection with a system of membranous tubes. Dr. W. B. Carpenter regarded the membranous tubes of Müller as solid fibrillar cords, proceeding from a similarly constituted envelope around the chambered organ, and he came to the conclusion that this fibrillar sheath, and the cords proceeding from it, constitute the central nervous system of the Comatulæ. This was afterwards confirmed by experimental evidence, and is now generally admitted by zoölogists.

The organ in question is a sac, divided into five radial compartments, enclosed by a thick envelope in connection with the axial cords. From the dorsal surface of this envelope processes are given off to the cirri, and from its margin arise interradially five short primary cords, which, passing upwards and outwards, bifurcate into right and left branches between the centrodorsal and radials. The ten secondary cords diverging from one another, enter the substance of the radials, and either unite in pairs, the right branch from one interradial meeting the left branch from the adjoining one (Figs. 3 and 4), or the two branches, as in *Encrinus liliiformis* (Fig. 5), without touching each other, proceed on separately to the costals. On reaching the first axillaries the two cords open out into two branches, right and left, and after traversing the plates, enter the right and left arms, respectively. In addition to the above connections, there is a circular or pentangular commissure, which, immediately after entering the radials, connects the various branches among themselves, and additional connections between the branches within the axillaries supply the arms (Figs. 3 to 4). The axial cords along the arms lie in tubular channels piercing the calcareous part of the various arm joints, each cord giving off alternately right and left branches, which enter the pinnules.

Chambered organs have been observed also in Stalked Crinoids, but the position is not quite the same as in the Comatulæ. While in the latter the organ is lodged within the centrodorsal, and is covered by the rosette,* it is in *Pentacrinus*, which has no centrodorsal, contained in a cavity formed by the radials above and the basals below. The five chambers of *Pentacrinus* are not closed at the bottom, but are continued down the stem as five vessels, systematically arranged around a central axis. These vessels were regarded

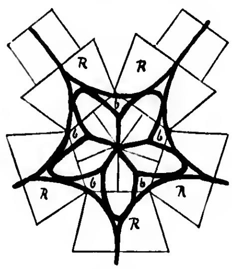


FIG. 3.

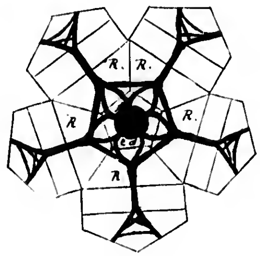


FIG 4.

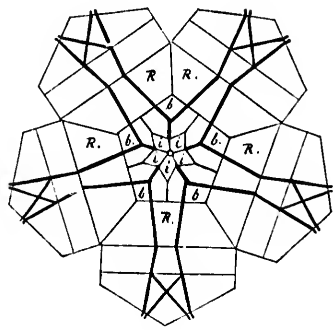


FIG. 5.

Fig. 3, position of the axial cords in the young *Antedon rosaceus* (after W. B. Carpenter); Fig. 4, their position in the adult (after A. M. Marshall); Fig. 5, in *Encrinus liliiformis* (after Beyrich).
*cd* = centrodorsal; *i* = infrabasals; *b* = basals; *R* = radials. The dark lines show the arrangement of the canals in the dorsal cup.

by Dr. P. H. Carpenter as homologous with the five openings around a single one on the underside of the calyx, and along the stem of *Cupressocrinus*, *Myrtilocrinus*, and *Gasterocoma*. Among recent Stalked Crinoids a chambered

* In most of the Comatulæ, the embryonic basals are metamorphosed into the structure known as the "rosette," which is enclosed within the radial pentagon, so as to be not visible externally.

organ has been observed in *Rhizocrinus*, *Bathycrinus*, and *Holopus*, and it existed probably in the other genera. Among Jurassic and later fossil Crinoids, axial canals, piercing the body of the calyx plates, are known to exist in the Apiocrinidæ and Eugeniacrinidæ (Holopidæ Jaekel), and they are readily recognized in the Triassic *Encrinus*, in some of the later Palæozoic Poteriocrinidæ, and in *Mycocrinus* and *Cutillocrinus*; but we have found no trace of them in the Camerata, except in *Steganocrinus pentagonus* (Plate LXI. Fig. 3), in which, so far as observed, the five or six proximal plates of their tubular appendages are pierced by a canal. Such canals occur upon the radials in some of the Cyathocrinidæ, the Cupressocrinidæ and Gasterocomidæ, and we may suppose that a chambered organ existed in these and other groups, if not in all Crinoids. In cases where grooves or canals for the reception of cords are not apparent, the cords may have rested against the inner wall of the plates.

### B. *The Convoluted Organ.*

In the abdominal cavity of Palæozoic Crinoids, the only organic structure that under very favorable conditions has been observed, is a peculiar skeleton which occupies the greater part of the cavity.

It is a large convoluted body, in its outlines resembling the shell of a *Bulla*, open at both ends. Its upper part rests directly beneath the origin of the ambulacra, the lower end within the basal ring without touching the plates. It is dilated above, contracted below, its lateral faces placed parallel to the inner walls of the calyx; the bottom truncated. In some species it is subcylindrical, with the vertical axis the longer, in others globose or even depressed globose. In coiling around its axis, the partition walls do not meet each other, but leave more or less wide interspaces. The convolutions vary in number from 2 to 4 according to species, and are, as they pass outward, directed from right to left. The walls in the usual preservation are thick, and perfectly solid, as they were described by Hall; but in transverse sections they frequently appear as if composed of two partitions closely fitted together, and closed along the edges. In some specimens, however, the walls are simple, and constructed of an extremely fine and delicate filigree work, composed of minute pieces or bars, with intervening meshes, which do not intersect at any uniform angle, but anastomose so as to impart a kind of irregular regularity to the form and size of the meshes. No such structure has ever been observed in the other specimens, in which the pores or meshes seem to have been obscured by heavy incrustations of silicious matter at both sides, and these incrustations may have produced the apparent duplication of the walls (Plate V. Figs. 1, 4, 9, and 12).

Among the many beautiful examples in the Wachsmuth collection at the Museum of Comparative Zoölogy, in which the convoluted organ is preserved, there are two unique specimens (Plate V. Fig. 11 and Fig. 10); the former showing the delicate porous texture, the other its position beneath the ambulacral skeleton. The collection contains also the remarkable specimen of *Macrocrinus verneuilianus* (Plate V. Fig. 8), in which the upper end of the organ is surrounded by a large annular vessel with five radial and five interradial openings. In this species the end of the outer fold turns into a narrow thickened strip, which ascends spirally toward a place in the direction of the anal tube. This structure differs somewhat from that of *Teleiocrinus* and other genera which have a thickened edge along the lower margin of the outer fold passing upward (Plate V. Figs. 1, 3, 12). In a specimen in our collection, either of *Strotocrinus* or *Teleiocrinus*, we succeeded in removing at one side the two outer folds, and exposed the third or inner fold (Plate V. Fig. 4), which has the form of a spindle, thicker at the middle and tapering to both ends. It seems that the innermost cavity in all cases is spindle-shaped, and that the inner end winds spirally upwards like a screw with rather sharp, roughened edges, — the so-called "collar" of Meek and Worthen. A connection with the ambulacra has not been satisfactorily observed in the specimens; neither the upper part of the organ, nor the ends of the ambulacral tubes, have been found in perfect preservation.

The function of the convoluted organ can only be conjectured, as no similar structure has been observed in recent Crinoids; but from its position it seems probable that it was connected with, or formed a part of, the digestive apparatus. If the latter was the case, the thickened outer end, leading toward the anus, may represent the hind gut.

## SYSTEMATIC PART.

### A. *Classification.*

In our classification of 1885,* under the belief that the Brachiate Crinoids were divisible into two groups so widely different in their ventral structure as to entitle them to rank as distinct orders, we adopted the name Pelmatozoa as a collective term to include the Crinoids, Blastoids, and Cystids. In so doing we followed the lead of Dr. P. H. Carpenter, who † brought forward this name as one which had been introduced by Leuckart in 1848; with the difference, however, that whereas Carpenter used it to designate the Stalked Echinoderms as a "branch" of the "phylum" Echinodermata, and to include the Crinoidea, Blastoidea, and Cystidea as classes of equal rank, we proposed to treat the same collective group as a "class" of the Echinodermata. We subdivided the Pelmatozoa into two subclasses, the first to contain the "orders" Cystidea and Blastoidea, the second the Crinoidea. The latter we divided into Palæocrinoidea and Neocrinoidea.

It has been shown by Agassiz ‡ that the name Pelmatozoa, although used by Leuckart at various times to include the Cystids and Crinoids, — presumably including in the latter Blastoids also, — can hardly be considered as well established; that it was not adopted by any writer on Crinoids before Carpenter, except Sir Wyville Thomson, and that Leuckart himself, from 1848 to 1879, used Crinoidea or Pelmatozoa indiscriminately in the same sense.

The term "Pelmatozoa," as having reference to the pedunculate condition, is objectionable, because in all three groups — Cystids, Blastoids, and Crinoids — there are many forms in which no stem is found, and some that apparently never had any. The latter is probably the case, among Crinoids,

* Revision, Part III. p. 78.
† Challenger Report on the Stalked Crinoids, p. 193 *et seq.*
‡ Calamocrinus Diomedæ, p. 8.

in *Marsupites* and *Uintacrinus*; while *Agassizocrinus*, *Edriocrinus*, and the Comatulæ are stemless in the adult. Among Blastoids, the stem is wanting in *Pentaphyllum*, *Tricœlocrinus* and *Eleutherocrinus*; and this is the case also in a large number of Cystids. The three divisions undoubtedly are nearer related to each other than to any of the other groups of the Echinoderms, not so much by reason of the stem, as because their habit of life is with the mouth upward, the body lying on its back or growing on a stalk, in contrast with the habits of Starfishes, Ophiurids and Urchins, which crawl about mouth downward, and the Holothurians, which swim with the mouth sidewise. Upon these characters, perhaps, the Echinoderms might be conveniently separated into three great groups; but in that case a new name should be adopted in place of "Pelmatozoa."

We are now prepared to accept the Crinoids, Cystids, and Blastoids as separate groups of independent rank; but what may be their exact relative importance, that is to say, what should be the exact size of the compartments to be provided for them in the scheme of classification, is purely a matter of opinion, and not of great consequence. The tendency of authors is more and more toward recognizing them as groups well distinguished from each other, and they are now ranked generally as independent classes.

There is in our opinion not the slightest doubt that the "Crinoidea," as proposed by J. S. Miller in 1821, were limited to Brachiate forms, or, to be technically accurate, to the Stalked Echinoderms with "articulate arms." This is clearly shown by his definition,* already quoted by us in a previous chapter. While including among his species both recent and fossil forms, Miller did not refer to his Crinoidea a single Cystid or Blastoid, although both must have been known to him. Cystids are abundant at the Dudley locality, from which he described some Crinoids, and a *Pentremites* had been figured in 1808 by Parkinson in his "Organic Remains," — a work with which Miller was no doubt familiar. The name "Crinoid," in the strict sense thus employed by Miller, has been sanctioned by the usage of practical naturalists ever since, and in our opinion all attempts to strip the term of its familiar signification, either by enlarging or restricting its meaning, will prove abortive. If von Zittel, instead of a new name for the Crinoids, had proposed some appropriate term for the larger group, — to include the Crinoids, Cystids, and Blastoids, — it would have been a very desirable improvement, and we believe would have been generally accepted.

* Natural History of the Crinoidea, p. 7.

While adhering, therefore, to the original definition of Miller for the Crinoids, and recognizing the Blastoids and Cystids as distinct groups, of relatively equivalent rank, we have to admit that the three types are connected by a number of remarkable intermediate forms, and that it is extremely difficult in many cases to ascertain whether certain forms are Crinoids or Cystids, or Cystids or Blastoids. It has been stated that Crinoids and Blastoids are distinguished from Cystids by their distinct pentamerous symmetry; that the Blastoids and Cystids, as opposed to the Crinoids, have no true arms; that the Blastoids have hydrospires, the Cystids calycine pores, *etc.*; but the best of these characters meet with exceptions. We find in certain Blastoids, and also in *Tiaracrinus* from the Devonian, and *Zophocrinus* from the Upper Silurian, only four radii; and even as late as the Mesozoic there are among the Plicatocrinidæ species with three, four, and six rays. *Porocrinus* has the calyx and arms of a Crinoid with calycine pores of a Cystid. *Hybocystis* has stumps of arms with recurrent ambulacra on three of its rays, and on the other two rays calyx ambulacra, which pass down the cup as far as the basals. The genus was described by Wetherby as a Cystid, by Etheridge and Carpenter as a transition form between Crinoids and Blastoids; while we have regarded it a Crinoid with strongly persistent Cystidean characters. *Caryocrinus*, which has always been considered a Cystid, has segmented pinnule-bearing arms like a Crinoid; but it has calycine pores and hydrospires, and according to Carpenter six rays. *Codaster* was made a Cystid by E. Billings, by Etheridge and Carpenter a Blastoid. *Stephanocrinus* was placed by Roemer among the Cystids, by Etheridge and Carpenter among the Blastoids, and we take it to be a Crinoid. *Asteroblastus* has calycine pores like a Cystid, and ambulacra and pinnules like a Blastoid.

These, and other facts that might be adduced, point to a common origin; but what may have been the exact line of derivation between the three groups is a problem that is difficult to solve. They are found side by side in the Lower Silurian; but while the Cystids ceased to exist at the end of the Devonian, and the Blastoids at the close of the Carboniferous, the Crinoids survived to the present day. From this it seems to be evident that the Cystids, as the lowest in rank and earliest in time, were the ancestral type, and the progenitors of the other two; but it is possible that the Crinoids preceded the Blastoids, although the latter became extinct before the close of Palæozoic time.

That the origin of the Crinoids must have dated back far beyond the

Silurian and perhaps Cambrian age, is indicated by the high state of development which some of their forms had acquired as early as the Trenton group, when they had in some cases almost completely thrown off their Cystid characters. A striking example of this among the Camerata is seen in the genus *Glyptocrinus*, in which we find associated with certain primitive characters a high degree of perfection. It is less perceptible among the Inadunata, in which, notably in the Hybocrinidæ, Cystidean features are strongly intermingled with the characters of the larval Crinoid. But even among them it is impossible with the knowledge we have, or are likely to obtain, to form a conjecture as to the group of Cystids from which they are originated, and this is readily explained if we consider that the two types followed independent lines of development, and departed from one another more and more in geological time.

The general tendency of the Crinoid type, taken as a whole, has been toward pentamerous symmetry, and in this they differ essentially from most of the Cystids. But the pentamerous tendency had to struggle with other tendencies, which in various ways from time to time carried one or the other of the subordinate groups far off in other directions. A disturbance of this kind was caused by the introduction of anal plates, by means of which the pentamerous symmetry was temporarily disturbed by a bilateral one, which for a time threatened to overshadow the former, until finally after the elimination of those plates the pentamerous symmetry was permanently restored. The phases through which the anal plates pass in geological time in the various groups are well represented by individual growth in the larva of *Antedon*, and have proved to be excellent characters for family and generic divisions.

The earliest fossil Crinoids have no special anal plate, and were more or less strictly pentamerous. Among the Lower Silurian Camerata the anal $x$ is represented only in the Reteocrinidæ and in the abberrant genus *Compsocrinus;* in all others the plate is wanting. It is absent also in the genus *Ichthyocrinus*, one of the earliest forms of the Articulata, and, as we think, the precursor of a large series of genera with anal plates. It probably was represented earlier in the Fistulata than in the other groups, as might be expected, for among them all tendencies toward further development seem to have been exhibited upon the posterior side.

But there were other influences, not due to the anal plates, and not directly traceable to anything shown by embryology, which not only disturbed the radial symmetry, but the bilateral as well, and strongly suggest that the Crinoids had to wrestle for a long time with the tendencies derived from their Cystid antecedents, manifesting themselves in a variety of irregularities, which from time to time characterized special groups. Such are the presence of compound radials in one or more rays; the variations in the form and composition of the proximal ring in the base; the non-arm bearing radials of *Baerocrinus*, *Atelestocrinus*, and *Tribrachiocrinus;* the irregular number of radials — more or less than five — of the Plicatocrinidæ; and the almost complete obliteration of symmetry among the Pisocrinidæ and Calceocrinidæ.

The division of the Crinoids into two orders: "Palæocrinoidea" and "Stomatocrinoidea" was proposed by us on account of the apparent difference in the conditions of the actinal portions of the calyx, whereby mouth and food grooves, and the ventral disk generally, of all Palæozoic Crinoids, without exception as we supposed, was covered by a special integument — the "vault" of antecedent literature — instead of being external and exposed to view. With the knowledge we then had this seemed to be a character morphologically of extreme importance, and it was so regarded by others. Under the order Palæocrinoidea we placed all Crinoids with covered mouth and closed food grooves, and under the Stomatocrinoidea those in which mouth and food grooves are exposed. The two groups were accepted by Carpenter, but he changed the name of the latter into "Neocrinoidea."

Another classification was introduced by Neumayr,* who proposed the name "Hypascocrinoidea" for all Crinoids in which mouth, ambulacral vessels, and *Saumplättchen* (the latter if present) are beneath the tegmen; and the "Epascocrinoidea" for those forms in which the ambulacra are not covered by the tegmen, but have external grooves, which are either exposed or closed by movable *Saumplättchen.* Under the latter he arranged all recent Crinoids with our Fistulata; under the former the Ichthyocrinidæ and Haplocrinidæ together with our Camerata. It is surprising that Neumayr's classification, while based like ours upon the condition of the mouth and surrounding parts, led to such different results. This must be attributed largely to the interpretation which he gave to the disk of *Cyathocrinus*, in which he took the vacant space found in the centre of imperfect specimens for the mouth, and to the fact that he was unacquainted with the ventral structure of the Ichthyocrinidæ.

* Die Stämme des Thierreiches, 1889, p. 462.

When we discovered that the ventral surface of *Taxocrinus*, and probably of all Ichthyocrinidæ, is covered by a disk almost like that of recent Crinoids, and that it possesses an open mouth and open food grooves, it was instantly apparent to us that a division upon the line of Palæozoic and Neozoic Crinoids could no longer be maintained. The moment this truth was recognized, it was found to be reinforced by other considerations which were fully set forth by us at the time.* It might have seemed practicable to retain the two grand divisions upon the same characters as before, by transferring the Ichthyocrinidæ to the division containing the recent Crinoids; but this would have made a change of the names unavoidable. Besides, the fact that those characters go back as far as the lowest Silurian was enough to suggest the gravest doubts whether the particular condition of the ventral covering was morphologically as important as we had supposed.

About the same time we came into possession of specimens of the Camerate genus *Platycrinus* with orals almost perfectly symmetric, and the covering plates of the ambulacra most regularly arranged. Considering that in this same genus there are species in which the tegmen is composed of as heavy plates as in any *Actinocrinus* with subtegminal ambulacra, the conclusion forced itself upon us that the plates of the tegmen in all these forms represent the same element, and that the most rigid "vault" of Palæozoic Crinoids is but a modified disk.

The change in our views was announced in our paper on "The Perisomic Plates,"† in which we gave up the Palæocrinoidea and Neocrinoidea as natural groups, and proposed in place of them the *Camerata*, *Inadunata*, and *Articulata*.

A separation of the older Crinoids into three divisions was attempted by us as early as 1877, and all that we have since learned, whether through our own observations or those of others, has tended to confirm their validity. Now that we have got rid of the imaginary line between Palæozoic and later Crinoids, we can better realize the importance of these groups, especially since we find that they can be applied to all Crinoids, recent as well as fossil.

We regard as the most important characters for dividing the Crinoids into orders: —

1st, the condition of the arms — whether free above the radials, or partly incorporated into the calyx.

* Proc. Acad. Nat. Sci. Phila., 1888, p. 350, *et seq.*

† Ibid., p. 345.

2d, the mode of union between the plates of the calyx — whether movable or immovable.

3d, the condition of the stem — whether the young joints were formed beneath the proximal ring of the calyx, or beneath the top stem joint.

The morphological importance of these characters is shown by the fact that among the earlier Crinoids they appear as well defined as among those of later epochs, which indicates that the origin of the three groups dates back to a much earlier time.

The CRINOIDEA INADUNATA represent the simplest form, their dorsal cup being composed invariably of only two rings of plates, or three when infrabasals are present. It has no supplementary plates, except an anal piece, but this is not represented in all of them. The radials at four sides of the cup are in lateral contact, and the arms are free from the radials up.

In the structure of the ventral disk we recognize two different plans; the one exhibiting the utmost simplicity, being composed exclusively of five large oral plates forming a pyramid; the other showing considerable complexity at the posterior interradius, which is drawn out into a sac or tube. Upon these two plans we divide the Inadunata into two subgroups: The INADUNATA LARVIFORMIA, and the INADUNATA FISTULATA, both embracing monocyclic and dicyclic forms.

The calyx of the *Larviformia* consists of but few plates; viz.: basals — occasionally infrabasals — radials and orals, the latter forming a closed pyramid which rests against the radials; the mouth is closed, and the ambulacra are not exposed to view. The arms are simple, non-pinnulate, one to each ray, and they are composed of long, quadrangular joints which, except upon the radials, are united by close suture. The anus is excentric, either piercing the posterior oral, or situated between the orals and radials, and is sometimes extended out to the end of a long, narrow tube. One can scarcely imagine a more complete parallelism than there is between these ancient Crinoids and the larval state of recent ones, and it was this that suggested the name of the group, which, as we believe, represents the most primitive type of the Crinoids generally. That we do not find the Larviformia prior to the Niagara, but only subsequent to the advent of the other groups, may be accounted for by the small size of their species. The calyx of *Allagecrinus Austinii* from the Scotch Carboniferous is no larger than a small grain of sand, and it is very possible that the earliest forms were altogether microscopic. The total absence of supplementary plates, and the compound nature of the radials in the earlier forms, are other primitive features characteristic of this group.

The *Fistulata*, in a general way, agree in the structure of the dorsal cup with the Larviformia. But while in the latter the disk is simple in the extreme, that of the Fistulata is highly specialized by means of the extravagant development of the posterior interradius, forming a tube or sac which often is drawn out to the full length of the arms. The sac rests upon the radials or is supported by the anal $x$, and frequently — not always — contains the anus. Owing to the large size of this sac, and the disturbances thereby produced, the whole calyx acquired a marked irregularity, which was still further increased in species with compound radials, so that the pentamerous symmetry, and the bilateral also, were often supplanted by asymmetry. The other interambulacral areas are but feebly developed, and are pushed over toward the anterior side. The anal opening is situated near the top of the sac, or at some place along its anterior side, and sometimes in front of the sac close to the mouth. The sac, at least in some groups, is pierced by pores, which we think had respiratory functions, similar to the water pores of recent Crinoids, in which also they are more profusely distributed at the posterior area than at any of the four other sides. In some groups, in which the sac is not perforated, we discovered upon the disk, directly behind the mouth, a poriferous plate, a sort of madreporite, which probably performed the same functions as the pores in the others.

The Crinoidea Camerata have a large number of supplementary pieces, which are distributed almost equally throughout the five sides of the calyx, by means of which the proximal arm plates for some distance are incorporated into the calyx, thereby increasing the capacity of the visceral cavity. All plates of the calyx are heavy and immovable, being united by close suture. The symmetry of the dorsal cup is either strictly pentamerous or sub-bilateral; we never find that asymmetry which is so characteristic of some of the Fistulata. The base is monocyclic or dicyclic, and mouth and food grooves are perfectly closed.

The Crinoidea Articulata agree with the Camerata in that their lower brachials take part in the calyx, and help to enclose the visceral mass; but their plates from the radials up are movable. The incorporation of the brachials took place by lateral union among themselves, by the introduction of supplementary plates, or by means of an incrusted or naked skin; and mouth and food grooves are exposed upon the disk. The base is dicyclic, but the infrabasals are fused with the top stem joint, which throughout this order is not the youngest joint of the stem.

To the Articulata we refer the Ichthyocrinidæ, and all Mesozoic and later Crinoids — recent and fossil — in which the new stem joints are introduced beneath the top joint. They are divisible into two suborders: —

I. The Articulata Impinnata, to include the Ichthyocrinidæ which are destitute of pinnules.

II. The Articulata Pinnata, to include those families in which pinnules are present.

That there exists a close resemblance between the Ichthyocrinidæ and Comatulæ — especially their earlier stages — is well shown by our illustrations on Plate VI. Figs. 13 to 20, and it is worth mentioning that no other form has changed so little in geological time as the genus *Ichthyocrinus*, which survived from the Lower Silurian to the Coal Measures, and which may be regarded as the ancestor of all Articulata.

The name "Articulata" was proposed by J. S. Miller, and adopted by Johannes Müller for a subdivision of the Crinoidea. The former referred to it *Apiocrinus*, *Encrinus*, and *Pentacrinus*, to which Müller added the Comatulæ. He defined the group as one in which the lower ray plates are connected laterally by a skin, which may be naked, or paved with irregular plates. From this definition we judge that his ideas of the group were substantially the same as ours, and we believe if Müller had known the Ichthyocrinidæ, he would have placed them together with the Apiocrinidæ and Comatulæ. His definition, however, is not complete enough, and it admits forms which in our opinion are widely different. We allude to the Encrinidæ and Pentacrinidæ, which differ from the Apiocrinidæ and Comatulæ in having the uppermost joint of the stem the youngest joint, whereas in the latter two it is not. That Müller admits *Pentacrinus* into this group we can understand — its lower brachials actually are united by a skin — but it is difficult to see why he added the genus *Encrinus*, in which the rays are free from the radials up. The Pentacrinidæ have through the Encrinidæ close affinities with the Poteriocrinidæ, and are probably their descendants; but if they are Inadunata, they represent an aberrant type, for their lower brachials, as stated before, are enclosed in the calyx. This departure from the Inadunate plan may perhaps be explained if we consider that the calyx of the Pentacrinidæ, owing to the reduction of the ventral sac, was incapable of holding the visceral mass without incorporating the lower brachials. As such the Pentacrinidæ may represent the last survivors of an exhausted type, or they are the progenitors of a new group.

After eliminating from the Articulata the Encrinidæ and Pentacrinidæ, and all Crinoids in which the top stem joint is the youngest joint of the stem, we have a well-defined group; but it may be asked whether the name Articulata can be retained for a group thus restricted and redefined. The name is most appropriate, and as the group is based largely on the character of Müller, we think it is just to the author to adopt his name. In case, however, other writers conclude that this course is inadmissible, we propose the name "Articulosa" to take the place of Articulata, to meet the contingency.

That our primary divisions are natural groups is further confirmed by the orientation of the base, which, when the proximal ring of the base is unequally tripartite, varies among the different groups. Comparing the base to the dial of a clock with the anal side at 12, it may be said that in the Impinnata the smaller infrabasal points to 2 o'clock; in the dicyclic Fistulata,* so far as observed, and in the *Antedon* larva, according to Bury, to 6 o'clock; and that the small basal in monocyclic Crinoids generally points to 7 o'clock, contrary to all Blastoids, in which it points to 5 o'clock. We have no explanation of these facts to offer, but they doubtless have an important bearing upon the derivation of the groups.

It is now well established that the value of a character for classificatory purposes is not always in proportion to its physiological importance; but depends more on its constancy throughout groups, and its correlation with other characters. The characters of any group are not fixed and rigid, but we must always be prepared to find as to one or more of them variations or departures from the typical form, indicating a transition toward, or connection with, some other group through that particular feature. We cannot expect absolute persistence of any one character, whether specific, generic, or ordinal, and the larger our collections the less persistent and fixed will we find the separate characters. But if we are reasonably happy in our identifications, we may expect to find greater reliance to be put upon the correlation of characters, so that while one or more of them will show a tendency to departure, the sum of all will exhibit a predominance which will hold the form in question within the given group. There is no hard and fast rule by which it may be determined that a certain character is of "family" or "generic" importance. It may be the one or the other according to cir-

* This does not hold good for the Fistulata since Mr. Bather — Crinoidea of Gotland, Vol. I. p. 152 — has found that the position of the small infrabasal is not constant in the Gotland species of *Gissocrinus*.

cumstances, and about all we can say of the "value" of any character is that its value is proportional to the extent to which it tends to combine subordinate groups. As a rule we may say that a character which passes down to earlier geological epochs, is of greater value in classification than one dating from a later period.

It has been stated that the supplementary plates afford excellent characters for dividing the Crinoids into primary divisions; but they are also of great importance in the separation of families. It may appear singular that plates whose chief function it is to fill up spaces between other plates, and which are of but secondary importance morphologically, should have so great a value in classification; but such is undoubtedly the case. The elimination of those plates from the calyx would reduce all Crinoids to a single group, and these would all be Larviformia. The introduction of supplementary plates into the simplest Inadunate type produces the Fistulata, Camerata, and Articulata, and all in their individual development necessarily passed through the Larviformia stage.

Among the supplementary plates, the anals unquestionably take the first rank. The absence of anal plates, their introduction into the calyx, and the relations they bear to adjoining plates — whether introduced between the radials or brachials, or between both of them — has been regarded as very important; but the same characters have not the same classificatory value in every group. The differentiations produced by the anal plates have been considered of family importance among the Camerata, but among the Fistulata and Impinnata appear to be of generic value only.

The nature of the base, whether composed of one ring of plates or two, is a valuable character for distinguishing families, but we thought it expedient to make an exception to this rule in the case of the Reteocrinidæ, under which we have united monocyclic and dicyclic forms. The number of basals and infrabasals is of generic value only.

The occurrence of inferradials among Inadunata and Articulata, and the modifications they undergo palæontologically, and their final disappearance, have furnished good generic characters.

Somewhat less important from a classificatory standpoint is the number of costals, although it was made a generic character among the Camerata; while in the Fistulata it has in some cases no significance at all.

The general structure of the disk affords good characters for dividing the Crinoids into ordinal and subordinal groups. It was the total absence of perisomic plates in the disk that suggested the Larviformia, and the sac-like prolongation of its posterior area the Fistulata; all Camerata have a rigid disk, contrasting therein with the Articulata in which the disk is pliable.

The condition of the ambulacra, whether resting upon the tegmen or being incorporated into it by means of their covering pieces, or whether constituting open furrows upon the disk, is of more than family importance; but the exposure of the covering pieces, and their concealment wholly or in part by the encroaching perisome, are not even reliable generic characters.

The presence or absence of orals, and their greater or less symmetry or asymmetry, have very little classificatory value, except in the Larviformia, in which they are the only plates of the disk.

The condition of the anus, whether in form of a simple opening directly piercing the calyx, or situated at the end of a tube, has been generally regarded as of generic value.

Of considerable importance is the presence or absence of pinnules, which is correlated with other characters by which very large families are distinguished, *e. g.*, the Cyathocrinidæ from the Poteriocrinidæ; and it is the name-giving character of the Pinnata and Impinnata.

The condition of the arms, their simplicity, their mode of branching, and the arrangement of their plates — whether uniserial or biserial — afford useful characters for distinguishing genera; but as all biserial arms are derived phylogenetically, as they are embryologically, from the uniserial ones, it must be expected that at a certain time both structures occur side by side in the same genus.

The construction of the stem, the form of the joints, the length of the internodes, have comparatively little value in the classification of Palæozoic Crinoids, and are of generic value only in rare cases. Perhaps if the stems were oftener and more completely preserved, it would help in the identification of species.

With regard to species, their recognition is to a considerable extent the expression of the individual opinion of the observer, and in large collections it is often difficult to distinguish between species and variety. So long as we have to deal with new forms, represented by unique specimens, the task is simple enough. But when large numbers of specimens are brought together, in different states of preservation, presenting different conditions of growth and size, and exhibiting the various shades of individual variation, it is not so easy to discover and define the points by which certain assemblages of these individuals agree with each other, and differ from others, with sufficient constancy to be called species. With but a single specimen in hand, and this imperfectly preserved, as is often the case, it is impossible to decide whether we have a good species or a mere variation, whether it is the young or the adult; and whether or not the distinguishing character represents a mere abnormal condition of some established species. In describing new species, therefore, the utmost caution is required, especially since the number of described species in America alone has increased to almost fifteen hundred. That a specimen comes from virgin soil, distant from any other known locality of the same horizon, does not make it a different species. The geographical range of species is much wider than formerly supposed, and careful comparison with authentic specimens of allied forms must always be made before a form can be recognized as a valid species. Among the characters to be considered as most important for distinguishing species, we recognize the form and proportions of the calyx; the relative proportions of the plates and their ornamentation; the number of arms and arm openings, the direction of the latter, and their distribution around the calyx, whether continuous or separated by the supplementary plates; the form and position of the orals, whether flat or tumid, symmetrically or asymmetrically arranged; the presence of "radial dome plates" or regular covering pieces, and other characters of a more specialized nature; not forgetting that some of them depend on the more or less adult condition of the specimen, and its preservation, and that in certain groups some of them are wholly worthless.

That a given character may be good in one group, and without any value for classification in another, is a fact so fully recognized at the present day that there is no need of citing instances to prove it. Every working naturalist has encountered striking illustrations of its truth.

To facilitate the identification of species among genera containing a large number of forms, we have arranged our descriptions so as to place species which are most closely related next to each other, thereby enabling the student to make satisfactory comparison with allied forms. In *Platycrinus*, which contains an unusually large number, we have arranged the species into subordinate groups.

It is not our intention to go into details upon the classification of the Inadunata, but a short review of them will be necessary for this work.

We have stated that we divide the Inadunata into Larviformia and

Fistulata. The former embrace the families Haplocrinidæ, Pisocrinidæ, Symbathocrinidæ, and Cupressocrinidæ; the latter the Hybocrinidæ, Heterocrinidæ, Anomalocrinidæ, Belemnocrinidæ, Gasterocomidæ, Catillocrinidæ, and Calceocrinidæ of monocyclic forms, and the Dendrocrinidæ, Cyathocrinidæ, Poteriocrinidæ, Astylocrinidæ, Encrinidæ, and Pentacrinidæ among dicyclic forms. The arrangement is substantially the same as that proposed by us in 1885, in Part III. of the Revision, except that we withdraw the Gasterocomidæ from the Larviformia, and place them among the Fistulata. This change was announced by us in 1890,* when we restricted the Larviformia to those Inadunata in which the orals rest against the radials, and the ventral surface is covered exclusively by the orals, *i. e.*, Crinoids which remain persistently in the larval state.

A different division of the Inadunata has been lately proposed by Mr. Bather,† who subdivided the Inadunata into "Monocyclica" and "Dicyclica;" but whether they should be ranked as suborders, he leaves as yet in doubt. In alluding to the Larviformia and Fistulata, Bather says these divisions "cannot well be maintained. Many genera hitherto included in the Larviformia have quite as good a ventral sac as some acknowledged Fistulata." We do not know of any group to which this remark can be applied, unless Mr. Bather undertakes to homologize the narrow anal tube of *Symbathocrinus* and *Pisocrinus* with the ventral sac of the Fistulata. *Symbathocrinus* has no ventral sac, but simply an anal tube, nor has it an anal plate, or perisomic pieces as we once supposed; its asymmetrical oral pyramid rests directly upon the radials, and its anal tube is supported by the radials and orals together. Bather further says: "they (W. and Sp.) excluded *Heterocrinus* and *Calceocrinus*, in which it has at all events never been proved that other plates beside orals occur in the tegmen." We supposed it was now admitted that the ventral sac represents morphologically the highly developed posterior inter-palmar area of the disk, as was proved by the position of the anus, which is situated either at the *anterior* side of the sac, or not within the sac at all, but in front of it (toward the oral centre) in the main part of the tegmen. Admitting this, the presence of the sac proves that the Heterocrinidæ had a complicated disk.

The case is very similar in the Calceocrinidæ and Catillocrinidæ. Both agree with the Larviformia in having no anal plate, at least no anal $x$; but

* Proceed. Acad. Nat. Sci. Phila., 1891, p. 355.

† The Crinoidea of Gotland, Part I., with ten plates (Stockholm, 1893), p. 20.

there are resting upon the radials what we take to be plates of the tube. These plates, which are crescent-shaped and extremely heavy, are longitudinally arranged, and pass up to near the top of the arms. The relation of these plates is not altogether clear, but they probably represent the heavy and solid plates of *Iocrinus*, which constitute the ridge along the posterior side of the sac; and we believe that the open groove at the anterior side was in the animal filled, as in the case of *Iocrinus*, by small disk plates, which may or may not have been perforated. This interpretation seems to us the most probable, and upon the strength of it we have placed both families under the Fistulata.

Bather's definition of the Monocyclica is short: "Inadunata with no infrabasals." But notwithstanding its brevity it meets with two exceptions: *Cupressocrinus* and *Myrtilocrinus*, which Bather referred to the Monocyclica with some doubt; both have an infrabasal disk. It will not help the matter to say that the plate in both groups is a top stem joint (centrodorsal), for the condition of the plate in *Cupressocrinus*, as well as in *Myrtilocrinus*, is very different from that under which the centrodorsal occurs in the Apiocrinidæ, Comatulæ, and Ichthyocrinidæ. Wherever that plate occurs, it is in dicyclic Crinoids, and the infrabasals are fused with it. When the fusion is complete there appears in place of the infrabasals a vacant space at the inner floor of the calyx between the basals; nothing of which is found in these two genera. Besides, the plate does not rest against the *outer* faces of the basals, as it should do if it were a top stem joint, but against their *inferior* faces, like the infrabasals of true dicyclic Crinoids.

Mr. Bather alludes to a structural peculiarity, which he thinks has "more weight in the classification than the varying extent of tegminal development." He says: "It will be seen from the ensuing remarks on *Pisocrinus*, *Calceocrinus* and *Herpetocrinus*, that a very large number of Inadunata Monocyclica closely resemble one another, either in the horizontal bisection of certain radials, a character which in Dicyclica is entirely confined to the right posterior radial, or in the greater development of certain other radials." He overlooks the dicyclic *Tribrachiocrinus*, which has three compound radials, and we find on examining the genera which he referred to the Monocyclica, that among the twenty-four only eight have three compound radials, and sixteen have not. Among the latter there are three with two compound radials, *Anomalocrinus*, *Ohiocrinus*, and *Baerocrinus*,* and three with a single

* In the latter, as we understand the structure, only the interradials became developed, but not the arm-bearing section.

one; the remaining ten genera have simple radials throughout. Neither do we find any remarkable development of certain radials, except when these are compound. All this is seriously in the way of making the presence or absence of infrabasals a subordinal character.

Bather claims that among the Dicyclica departures from the pentamerous symmetry of the cup plates occur only in the right posterior radial. Exceptions to this, however, are found in *Atelestocrinus* and *Nanocrinus*, in which the symmetry is disturbed by the anterior radial, and in the latter genus by the right antero-lateral together with the anterior.

Bather's researches were largely devoted to the Dicyclica of the Niagara and Wenlock age, which he divided into three principal families: the "Dendrocrinidæ," the "Cyathocrinidæ," and the "Decadocrinidæ;" and in addition to them he recognized two smaller families, the "Euspirocrinidæ" and "Carabocrinidæ," the latter unrepresented in Europe.

The Dendrocrinidæ are defined by him as follows: "Dicyclica, with *R′* alone, or with anal *x* alone, or with *R′* and anal *x*, or with a radianal, anal *x* and one plate of the tube, in the anal area of the dorsal cup; with broad radial facet; with dichotomous arms, that may or may not develop pinnules; with a tegmen composed of small plates, and with a ventral tube that is unusually long and transversely flattened." He states that the family is distinguished from the Decadocrinidæ by the continuous dichotomy instead of the single bifurcation of the arms; that their anal *x*, unlike that of the Cyathocrinidæ, is always associated with other anal plates; that the radials have a wide, slightly specialized facet; and that their tegmen is more delicate. The Dendrocrinidæ are said to be represented in America in the Hudson River group by *Dendrocrinus*, in the Devonian — both in this country and in Europe — by *Homocrinus*, and in the Carboniferous by *Parisocrinus*, *Poteriocrinus*, and *Scaphiocrinus*, which agree in the structure of the anal area; the three latter with pinnules, the former without them. The presence or absence of pinnules, and the structure of the arms, he makes the leading characters for distinguishing the genera.

He defines his second family, the Cyathocrinidæ, as having "no radianal or tube plate in the anal area of the dorsal cup; with anal *x* either present in the cup or raised above it; with five arms, simple and dichotomous; with tegmen rather solid." He refers to it *Cyathocrinus*, *Gissocrinus*, and their descendants, with the subdivisions Cyathocrinites, Achradocrinites and Codiacrinites, of which the latter have no anal at all, and some of their genera have an inferradial, or a radianal, while others have not.

The Decadocrinidæ, his third family, are defined as follows: "Dicyclica, in which the arms bifurcate; each main branch bearing armlets or pinnules, with from none to three anal plates in the dorsal cup, supporting a tube, of which the lumen is usually flattened transversely, and the plates plicated, with a tegmen composed of numerous small plates, very rarely distinguishable." The family is said to embrace such forms as *Botryocrinus*, *Barycrinus*, *Atelestocrinus*, *Scytalocrinus*, and finally *Oncocrinus*, *Eupachycrinus*, *Stemmatocrinus*, and *Encrinus*, — in our opinion the most heterogeneous assemblage of genera imaginable. It is not even true that they all have ten main arms; some of them have but five, others seven, nine, twelve, or even fourteen; and these modifications apparently occur within the limits of a genus, — proof enough that the number of arms is a most unreliable character in classification.

Another objection is that the family includes forms with pinnules and without them. Bather's views respecting the pinnules are rather peculiar. He expresses the opinion * that the development of pinnules by itself cannot be taken as a character indicative of divergence, and he undertakes to prove this by the genus *Botryocrinus*, of which he asserts that "the Swedish species have armlets and not pinnules," but "the common Dudley species undoubted pinnules." That the appendages of the latter are pinnules and not arms, he probably deduced from the fact that the branches of this species are somewhat smaller and arranged regularly from alternate joints. In discussing the evolution of the arms, Bather assumed † that armlets preceded the pinnules, and that when finally the armlets became small, ceased to branch, and were regularly placed on alternate sides of successive joints, they were called pinnules. This explanation is not satisfactory, as it would indicate that the smaller appendages are derived from the larger ones. It seems to us more probable that the armlets are true arm branches whose development was arrested; and we believe that every species of *Botryocrinus* has armlets, and that pinnules are not represented in any of them. *Botryocrinus decadactylus* we take to be morphologically in a similar condition to *Steganocrinus araneolus* (Plate LXI. Fig. 2 *a*); and we think that in both of them every joint of the main arms bears an armlet, whereas those species of *Botryocrinus* in which the armlets are given off at intervals are in the condition of *Steganocrinus sculptus* (Plate LXI. Fig. 1 *a*).

* Ann. and Mag. Nat. Hist., May, 1890, pp. 373–376.
† Ibid., p. 374.

But while the armlets of the Silurian *Botryocrinus* bear no pinnules, those of the Subcarboniferous *Steganocrinus* give off pinnules from the armlets.

Bather's classification and theories respecting the evolution of the arms are open to many criticisms, and are certainly not confirmed by a study of the Carboniferous Fistulata. He cannot put together certain Poteriocrinidæ with the Dendrocrinidæ, and others with the Decadocrinidæ, nor place the non-pinnulate *Homocrinus* and *Parisocrinus* in a family with pinnule-bearing forms. His classification is based principally upon two things: the presence or absence of infrabasals, which he makes a subordinal character, and the relations of the plates at the anal side among themselves and toward adjoining plates, upon which he separates the families. He was perhaps not aware that in *Barycrinus* the radianal may be present or absent in the same species, and that *Parisocrinus* would be substantially identical with *Cyathocrinus* but for the presence of the radianal. As family characters he also relies upon the mode of branching in the arms, and the structure of the tegmen, which latter he has been able to observe in only a few genera. The remarkable development of the posterior area into a ventral sac, which in 1890 was regarded by him as an excellent *ordinal* character, is omitted altogether in his present classification.

While therefore we cannot agree with Mr. Bather upon his classification, we fully acknowledge the excellence of his specific and generic descriptions in his late work on the Swedish Inadunata, and the many fine observations which he has brought out. His discoveries upon the orientation of the radials in the Pisocrinidæ and Calceocrinidæ are of the utmost value, and have thrown new light upon these difficult groups.

We regard as the best family distinctions among the Fistulata the presence or absence of infrabasals, the presence or absence of pinnules, and the relative size of the ventral sac. The structure of the tegmen, if we knew more about it, might perhaps also afford good distinctions; but the modifications that occurred at the anal side of the cup, and the mode of branching of the arms, can be utilized only for distinguishing genera. The biserial arm structure did not obtain a foothold among the Inadunata until near the close of the Subcarboniferous, and at no time became a constant character. More important for generic separation is the mode of union between the radials and brachials, and the form of the facet — whether horse-shoe shaped or forming a straight line; also the form of the ventral sac, and whether one or more of the radials are compound.

The least departure from the structure of the Larviformia toward the Fistulata is found in the genus *Carabocrinus*, in which the tegmen is composed of five asymmetrical orals, meeting laterally and by their inner ends, four of them resting against the radials, the posterior one being separated from them by a number of irregular perisomic pieces, which enclose a short anal pyramid. Somewhat higher differentiated is the tegmen of *Cyathocrinus alutaceus* Angelin — *C. ramosus* Bather — (Plate III. Fig. 6), whose ambulacra are subtegminal, but the orals are separated from the radials by a narrow belt of perisome; contrary to other species of *Cyathocrinus*, in which the ambulacra rest upon the tegmen, and the orals are, or seem to be, in a state of resorption. In *Hybocrinus*, the ventral sac is as small as in *Carabocrinus*, and it has large orals resting against the radials; but the lateral edges of the plates are covered by the *Saumplättchen*. The Cyathocrinidæ have a large ventral sac, and in the tegmen a madreporite, which was probably unrepresented in the Poteriocrinidæ, in which the sac itself is perforated. The ventral sac made its appearance in the Hybocrinidæ, Carabocrinidæ, and Anomalocrinidæ as a very insignificant protuberance; in the Heterocrinidæ, Belemnocrinidæ, and especially in the Cyathocrinidæ, and Poteriocrinidæ, it attained enormous dimensions, but dwindled down in the Encrinidæ to almost nothing, although some of them still have well defined anal plates. We do not restrict the Encrinidæ to forms without anal plates, such as *Encrinus*, *Stemmatocrinus*, and *Erisocrinus;* but include among them the genera *Eupachycrinus*, *Cromyocrinus*, *Ceriocrinus*, and *Oncocrinus*, in which the anal area passes through all possible transition stages. We make the reduced size of the sac, and the highly differentiated articulation between the radials and brachials, the distinctive characters of the family.

The CAMERATA constitute a compact and well limited natural group, and they are a highly specialized type, which by extraordinary development reached a stage of extreme differentiation, and produced a ventral structure apparently so different from that of other groups, that it was for a long time found impossible to homologize its plates with those of the other Crinoids. They represent a type of rapid culmination and development, possessing already in the earliest known forms well defined pinnules, and the biserial arm structure in most of their families being permanently established at the close of the Silurian. The organization of the Camerata may not be intrinsically higher than that of the other groups, but they very clearly represent a higher state of development than *Haplocrinus* or *Symbathocrinus*, in the sense that *Actinocrinus* is a more advanced type than *Platycrinus*. The two former represent the larval state of the Camerata, while *Platycrinus* is a sort of transition form, in which the Camerate stage has not reached its full development.

The Camerata existed at the beginning of the Silurian, and survived to the close of the Subcarboniferous, with a feeble reminiscence in the Coal Measures. But although they developed some very remarkable and short-lived forms in the Silurian — such as the Calyptocrinidæ and Crotalocrinidæ — the type is pre-eminently a Subcarboniferous one. In that age they reached an extraordinary development, not only in the abundance with which they flourished, both as to numbers and variety, but also in extravagance of form and size in every one of their leading families. In the lower Carboniferous the Camerate type seems to have achieved the summit of its possibilities, for extinction followed rapidly after, and at the close of the Keokuk epoch there was scarcely a remnant of the typical section left, and at the end of the Kaskaskia the whole group, so far as Palæontology informs us, was practically extinct.

The Camerata fall naturally into two sections: —

I. Those in which the lower brachials and interradials form an important part of the dorsal cup.

II. Those in which the brachials retain the form and small size of arm plates, and the interradials are almost exclusively confined to the tegmen.

The first of these represents the typical Camerata, of which an *Actinocrinus* is a characteristic example. It includes the Reteocrinidæ, Rhodocrinidæ, Thysanocrinidæ, Melocrinidæ, Calyptocrinidæ, Batocrinidæ, and Actinocrinidæ. This section reached its culmination among the Actinocrinidæ in the genus *Strotocrinus*, of which in some species the rays are incorporated as high as the twelfth order of brachials.

The second, or non-typical, section represents a stage in which the modification of the Inadunate type by Camerate tendencies only progressed to a limited extent, as shown by *Platycrinus* and allied forms. It includes the Platycrinidæ, Hexacrinidæ, Acrocrinidæ, and Crotalocrinidæ. In this section the Camerate type was not perfectly attained, but its development was checked. This may have been due to the large size of the radials, and the comparatively small size of the succeeding brachials, which retained permanently the condition of free arm plates. The species of this group are intermediate between the Inadunata and the typical Camerata, their lower arm joints taking part in the composition of the calyx by means of plates which combine the functions of interbrachials and interambulacrals, and which, properly speaking, are plates of the disk. Another peculiarity characteristic of this section is the presence of a large facet upon the radials, in which the lower brachials are buried, and a brachial of higher rank meets the interradials, and sometimes the radials.

The question has been asked whether the Crotalocrinidæ should not be placed under the Inadunata, instead of the Camerata. They certainly represent an intermediate form, having some characters even of the Articulata. But their lower brachials are more or less connected with plates of the calyx, and the covering plates of the ambulacra, unlike those of the Inadunate Crinoids, are rigidly incorporated into the tegmen. They are morphologically in the same condition as the other families of this section, except for the dicyclic base, and represent, as we conceive, only a different degree of departure from the Inadunate plan.

The typical section of the Camerata appears to have been the first in time. It was well defined in the Lower Silurian, where it was represented both by dicyclic and monocyclic forms,— the Rhodocrinidæ on the one hand, and the Batocrinidæ on the other. They flourished about the same period, culminated together in the Burlington epoch, and disappeared almost simultaneously, the one in the Keokuk group, the other in the Warsaw limestone. In the Lower Silurian there was another family — the Reteocrinidæ — in which the structure of the base seems to have been subordinate to other characters, and we found it advisable to include among them monocyclic and dicyclic forms; it was short-lived, not surviving the Hudson River group. The Thysanocrinidæ and Calyptocrinidæ, the former dicyclic, the latter monocyclic, came to light in the Upper Silurian, with a very small beginning for the former in the Hudson River; they existed for a time in considerable abundance, but perished soon, only a few straggling forms surviving to the Devonian. Of the monocyclic families, the Melocrinidæ were the earliest, ranging from the Trenton to the Hamilton, where they seem to have been abruptly cut off. The other great monocyclic family, the Actinocrinidæ, appeared, culminated, and disappeared in the Subcarboniferous.

The non-typical section made a good beginning in the Upper Silurian with its only dicyclic family — the ephemeral Crotalocrinidæ — and the Platycrinidæ, represented by five genera, of which four expired before the close of the epoch. The surviving Platycrinidæ had a feeble representation in the Devonian, but during the Subcarboniferous attained in the genus *Platycrinus* a wealth of forms which had no equal before or afterwards in any other group. The struggle for existence was kept up in this section by the Hexacrinidæ long after the last typical Camerate Crinoid had disappeared, and the expiring effort of an exhausted type is seen in the Coal Measures in the form of the diminutive *Acrocrinus Wortheni.*

It appears, therefore, that the typical Camerata do not represent the last of them in point of time, but that either their final efforts at perpetuation were carried on in connection with a tendency to revert to the Inadunate type, or the greatest persistence was manifested by that form of the Camerata which had departed from it the least.

The change from the pentamerous to the bilateral symmetry consequent upon the introduction of an anal plate into the ring of the radials, was perhaps the most important modification that took place during the palæontological history of the Camerata, and it occurred within the range of our knowledge of the group. The symmetry of the dorsal cup, which throughout the Trenton group had been more or less perfectly pentamerous, was disturbed in the Hudson River group, in both dicyclic and monocyclic forms. In the former, four of the truncated, heptagonal basals of the Rhodocrinidæ were reduced to pointed hexagons in the Thysanocrinidæ, and the interradial plates separating the radials disappeared from four sides, that at the fifth retaining its position, and serving as an anal plate. The Rhodocrinidæ were a long-lived family, appearing in the oldest Silurian, and persisting to the climax of the Camerata in the Subcarboniferous, — the strange, extravagant *Gilbertsocrinus* being their last survivor; while the Thysanocrinidæ scarcely survived the Silurian.

Among monocyclic forms the disturbance of symmetry was caused by the interposition of an anal plate between the posterior radials, which converted their pentagonal base into the hexagon of the Batocrinidæ and Hexacrinidæ. The pentagonal base, though reinforced in the Niagara by the Calyptocrinidæ, disappeared from the typical Camerata with the Melocrinidæ in the Hamilton; while the hexagonal base, with its accompanying anal plate, continued with great vigor in the Batocrinidæ and their offshoot, the Actinocrinidæ, throughout the period of greatest development of the group, and until the extinction of the typical section in the Subcarboniferous.

In the non-typical section, we have among dicyclic forms no example of a symmetrical base, the Crotalocrinidæ having a truncated posterior basal supporting an anal plate. But among monocyclic forms the anal plate is unrepresented in the Platycrinidæ, in which the base forms a pentagon. The introduction of the anal plate occurred in the Hamilton group, and produced the hexagonal base of the Hexacrinidæ. The two groups thenceforward flourished side by side to the middle of the St. Louis group, when the Platycrinidæ became extinct; while the Hexacrinidæ and their offshoot, the Acrocrinidæ, continued until the extinction of the Camerata.

We have not attempted to construct a genealogical tree for the Crinoids, or a branch of one for the Camerata, because such representations are generally unsatisfactory, and in this case the tree would have to be constructed too much upon imagination. Besides, our task is an humbler one. We have rather preferred to content ourselves in this respect with giving the general facts which our investigations seem to pretty well establish, and such interpretation of them as appears to us reasonably consistent therewith. Within these limits we have hoped that our generalizations may help to form a stable foundation upon which others may raise more ambitious structures.

There is no doubt that the Crinoids, by reason of their great geological range, and capacity for individual variation due to their complicated structure, offer one of the most inviting fields for demonstrating the principles of evolution. They afford a good illustration of the principle that individual development finds a parallel in a general way, in the phylogenetic history of the group. But while recognizing this truth, and confirming it by the many interesting proofs which our studies disclose, we must beware of expecting to find lineal succession, or of assuming that a form found flourishing in any given epoch is necessarily more highly organized than those occurring in previous epochs. The Palæozoic Crinoids represent in a broad sense the larval stages of recent Crinoids; but there are many cases in which the tendency seems to have been one of retrogression instead of progression. *Haplocrinus*, with its closed pyramid of five orals, is probably the most primitive type found in our collections, and yet it is a Devonian genus. The great family of the Ichthyocrinidæ, whose oral condition is substantially on a par with that of many recent Crinoids, occurred abundantly in the Silurian. It is also impossible to tell, except perhaps in a very general way, which one of a number of variations marked the line of succession; or in other words which was for the time being the racial characteristic carrying all others along with it, even though many of them may seem more important. For the same reason we cannot point out the exact consanguinity of groups which are apparently related by one or more characters. For we find that when a type starts on a career of development on a specialized line and runs its course, other characters for the time being subordinated to it follow in more or less parallel successions. So that it may come to pass that at a certain time we find two types apparently belonging to different lines of development, which have reached a concurrent condition in some other important character, and we cannot say through which of them the thread of consanguinity has been carried. For instance, in the non-typical Camerata we have the Platycrinidæ without an anal plate accompanied and succeeded by the Hexacrinidæ, in which that plate is present. In the typical section the Melocrinidæ are followed by the Batocrinidæ and Actinocrinidæ in similar succession. But (according to our palæontological record) the symmetric Platycrinidæ appear at a somewhat later period than the symmetric Melocrinidæ; — and as we do not find in the non-typical section any symmetric predecessors of the Platycrinidæ, we would be inclined on this ground to infer that they were derived from the Melocrinidæ. But here we are met by a greater difficulty, for this involves the illogical supposition that the Platycrinidæ — a family of the least development of the Camerate type — are derived from one much more highly organized in that particular line.

The trouble is that all our generalizations are necessarily based upon the Crinoids as they are represented *in our museums*, and not upon the Crinoids as they actually existed in geological time, which is a very different thing. It is like trying to reconstruct a book from detached fragments of the chapters, some of them written in hieroglyphics for whose decipherment the key has not yet been found. We are accustomed to speak of the imperfection of the geological record, but it is doubtful if in our practical studies we always bear in mind what this really means. To say nothing of the periods antedating the Silurian, in which substantially all vestiges of life are obliterated by metamorphism; of the accumulations of fossiliferous strata which have been destroyed by erosion during periods of elevation of the sea bottom; of the strata which over three fifths of the earth are submerged beneath the ocean; of the great regions unexplored, or covered with ice, snow, or sand; of the equally extensive areas in which the fossiliferous rocks of one formation are buried under those of succeeding ones; — leaving all this out of consideration, how much do we actually know of the life represented in the rocks accessible to us? Nearly all the known Silurian Crinoids come from the outcroppings of the strata at two localities in Europe, and three or four in America. The Devonian exposures producing well preserved specimens are even more limited. The Lower Carboniferous collections are better and more widely distributed, but are insignificant after all. Take the Burlington and Keokuk limestones, which in a few localities have produced more Crinoids in number and species than any other formation. They consist of several hundred feet of strata almost entirely composed of the comminuted remains of countless myriads of Crinoids — fragments which are worthless to the Palæontologist. It is only rarely that a thin layer is found in which the calcareous skeletons are preserved well enough for study; — little basins of limited extent, in which, during a period of temporarily quiet waters, the Crinoids lived, died, and were imbedded at sufficient depths to escape the detructive effects of shore action. If the collector happens to be present when one of these colonies is uncovered by the quarrymen, the specimens may be rescued for the benefit of Science. But it is an even chance that they will be buried in the debris of the quarry, broken up for ballast, or walled up in the foundation of a building, and thus be lost again. Out of the thousands of square miles in which these rocks lie nearest the surface, all the collections that have ever been made represent only the imperfect gleanings of not more than a few acres. If it be supposed that we get, even in this way, a fair representation of the crinoidal life of that period, the answer is that almost every new discovery of "nests" or "colonies" of good specimens brings to light new forms, and that species or genera hitherto very rare are often suddenly found within a limited space quite abundantly. In the Upper Coal Measures, to judge from our books and museums, one would suppose that Crinoids were well-nigh extinct. Scarcely a dozen species are known, and most of them only by their lower calyx plates. Yet there are many beds in this formation which extend over hundreds of thousands of square miles from the Missouri Valley far into the Rocky Mountains and tilted up along their flanks, which are completely filled with fragments of Crinoids. Suddenly the collectors at Kansas City, who have studied these rocks for years, discover an abundant deposit of well preserved specimens in a shale so soft that a few minutes rain dissolves them into unrecognizable fragments.

The importance of these observations, as a practical matter, is sufficiently shown by the fact that the discovery of a single specimen may sometimes throw new light upon important questions, and require the undoing of much previous work; — as was illustrated in the case of the disk of the Ichthyocrinidæ, and by de Loriol's discovery of small infrabasals in two species of *Millericrinus*, which made important changes in the classification imperative.

## DEFINITION OF THE CRINOIDEA AND THEIR PRIMARY DIVISIONS.

### Class CRINOIDEA.

Echinoderms which during part or all of their life were attached to other objects, either by means of a stem or directly by the abactinal side of the calyx. The visceral mass enclosed by a limestone test or calyx, constructed of plates symmetrically arranged, and giving off well defined, free arms from the sides. Mouth directed upwards.

I.

Crinoids in which the arms are free above the radials. The top joint the youngest in the stem . . . . . . . . . . . . . Order INADUNATA.
  A. Disk composed of orals only. Ambulacra subtegminal Suborder Larviformia.
  B. Posterior side of the disk extended into a sac. Ambulacra supra-tegminal . . . . . . . . . . . Suborder Fistulata.

II.

Crinoids in which the lower brachials take part in the dorsal cup. All plates of the calyx united by close suture. Mouth and food-grooves closed. The top joint the youngest in the stem. Order CAMERATA.

III.

Crinoids in which the lower brachials are incorporated into the calyx either by lateral union with each other, or by supplementary plates, or a calcareous skin. All plates from the radials up movable. Mouth and food-grooves exposed. The top stem joint fused with the infrabasals, and not the youngest joint of the stem . . . . . . . . . . . . . . . . . . . Order ARTICULATA.
  A. Arms non-pinnulate . . . . . . . . . . . . . . Suborder Impinnata.
  B. Arms pinnulate . . . . . . . . . . . . . . . . Suborder Pinnata.

## CAMERATA.

### *Analysis of the Families.*

#### I. Typical Section.

Lower brachials and interbrachials forming an important part of the dorsal cup.

A. Interradials ill defined.
   The lower plates of the rays more or less completely separated from those of other rays, and from the primary interradials, by irregular supplementary pieces. Anal interradius divided by a row of conspicuous plates. (Dicyclic or Monocyclic) . . . Reteocrinidæ.

B. Interradials well defined.
   1. Dicyclic.
      *a. Radials in contact except at the posterior side* . . . . . Thysanocrinidæ.
      *b. Radials separated all around* . . . . . . . . . . . . Rhodocrinidæ.
   2. Monocyclic.
      *a. Radials in contact all around.*
         Symmetry of the dorsal cup, if not strictly pentamerous, disturbed by the introduction of anals between the brachials only . . . . . . . . . . . . . . . . Melocrinidæ.
         Arms borne in compartments formed by partitions attached to the tegmen. Dorsal cup perfectly pentamerous. Plates of calyx limited to a definite number . . . . . . . . Calyptocrinidæ.
      *b. Radials in contact except at the posterior side, where they are separated by an anal plate.*
         First anal plate heptagonal, followed by a second between two interbrachials . . . . . . . . . . . . . . . Batocrinidæ.
         First anal plate hexagonal, followed by two interbrachials without a second anal. Arms branching from two main trunks by alternate bifurcation . . . . . . . . . . Actinocrinidæ.

#### II. Non-Typical Section.

Brachials and interbrachials but slightly represented in the dorsal cup.

1. Monocyclic.
   *a. Radials in contact all around. Base pentagonal* . . . . Platycrinidæ.
   *b. Radials separated at posterior side by an anal plate. Base hexagonal.*
      Basals directly followed by the radials . . . . . . Hexacrinidæ.
      Basals separated from radials by accessory pieces . . Acrocrinidæ.
2. Dicyclic.
   *Radials in contact except at the posterior side* . . . . . Crotalocrinidæ.

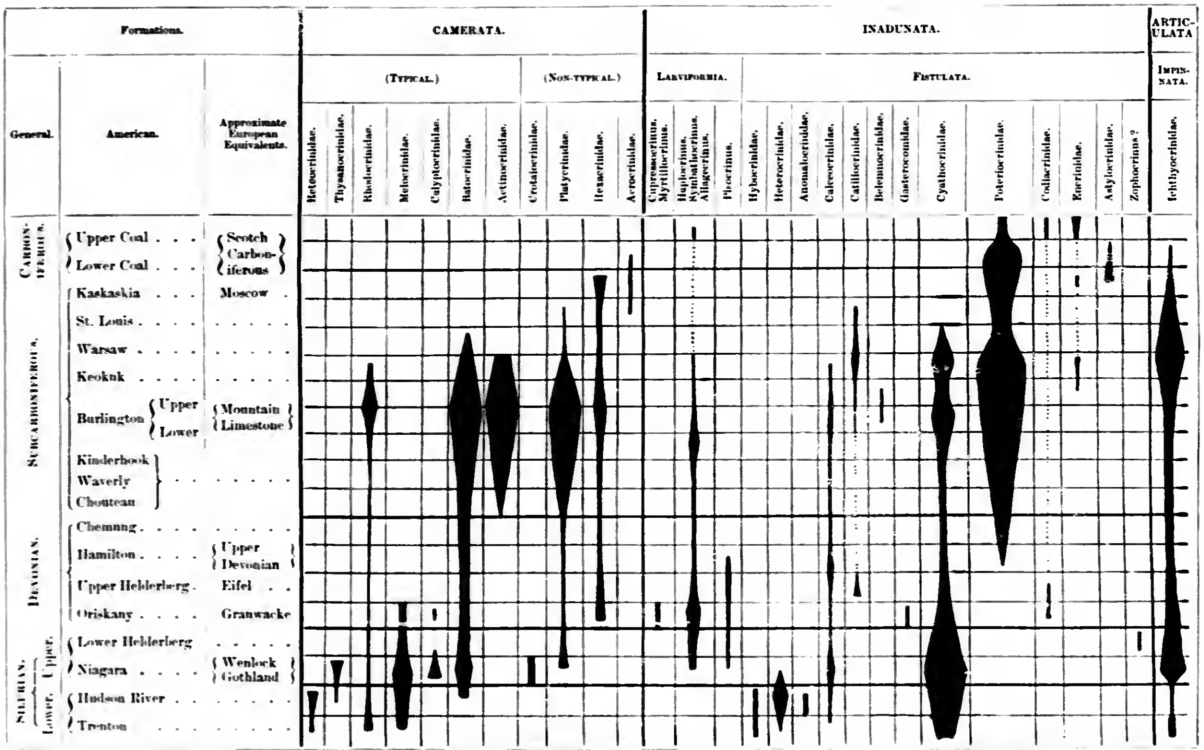
## GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF THE CAMERATA.

Open figures indicate American Species, those marked ( ), European.

NUMBER OF SPECIES.

| Formations. | | | Typical Form. | | | | | | | Non-typical Form. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General. | American. | Approximate European Equivalents. | Reteocrinidæ. | Thysanocrinidæ. | Rhodocrinidæ. | Melocrinidæ. | Calyptocrinidæ. | Batocrinidæ. | Actinocrinidæ. | Crotalocrinidæ. | Platycrinidæ. | Hexacrinidæ. | Acrocrinidæ. |
| Carboniferous. | Upper Coal Measures | . . . . | .. | .. | .. | ... | ... | ... | .. | .. | .. | ? | 1 |
| Subcarboniferous. | Kaskaskia . . . . | Moscow . | .. | .. | .. | ... | ... | ... | .. | .. | .. | 11 | 1 |
| | St. Louis . . . . | . . . . | .. | .. | .. | ... | ... | ... | .. | .. | 2 | 8 | 1 |
| | Warsaw . . . . | . . . . | .. | .. | .. | ... | ... | 6 | .. | .. | 1 | 5 | .. |
| | Keokuk . . . . . | . . . . | .. | .. | 3 | ... | ... | 41 | 5 | .. | 4 | 6 | .. |
| | Burlington, Upper | | .. | .. | 6 | ... | ... | 42 | 18 | .. | 14 | 7 | .. |
| | | Mountain Limestone | .. | .. | (9) | ... | ... | (1) | (20) | .. | (26) | (9) | .. |
| | Burlington, Lower | | .. | .. | 8 | ... | ... | 30 | 30 | .. | 28 | 6 | .. |
| | Kinderhook, Waverly, Chouteau . . | . . . . | .. | .. | 3 | ... | ... | 8 | 8 | .. | 10 | 3 | .. |
| Devonian. | Chemung . . . . | . . . . | .. | .. | .. | ... | ... | ... | .. | .. | 1 | 2 | .. |
| | Hamilton . . . . | Upper Devonian | .. | .. | 3 | 13 | ... | 14 | .. | .. | .. | 2 | .. |
| | Upper Helderberg . | Eifel . . | .. | .. | (4) | 8 (7) | (1) | (3) | .. | .. | (2) | (24) | .. |
| | Oriskany . . . . | Grauwacke | .. | .. | (1) | 2 (12) | ... | ... | .. | .. | . | .. | .. |
| Silurian. Upper. | Lower Helderberg . | . . . . | .. | .. | .. | 4 | ... | ... | .. | .. | 3 | .. | .. |
| | Niagara . . . . | Dudley Gotland | .. | 14 (7) | 3 (3) | 16 (15) | 21 (18) | 8 (48) | .. | (4) | 3 (5) | .. | .. |
| Silurian. Lower. | Hudson River . . | . . . . | 6 | 2 | 1 | 5 | ... | 2 | .. | .. | .. | .. | .. |
| | Trenton . . . . | . . . . | 1 | 8 | 8 | 6 | ... | ... | .. | .. | .. | .. | .. |
| | Total American . . . . | 464 | 7 | 16 | 35 | 54 | 21 | 151 | 61 | .. | 66 | 50 | 3 |
| | Total European . . . . | 219 | .. | (7) | (17) | (34) | (19) | (52) | (20) | (4) | (33) | (33) | .. |
| | Grand Total Species . . . | 683 | 7 | 33 | 52 | 88 | 40 | 203 | 81 | 4 | 99 | 83 | 3 |

TABLE SHOWING THE GEOLOGICAL RANGE OF THE PALÆOZOIC CRINOIDS.



## B. *Descriptive.*

## RETEOCRINIDÆ W. and Sp. (1885).

THE LOWER PLATES OF THE RAYS MORE OR LESS COMPLETELY SEPARATED FROM THOSE OF OTHER RAYS, AND FROM THE PRIMARY INTERRADIALS, BY IRREGULAR SUPPLEMENTARY PIECES. ANAL INTERRADIUS DIVIDED BY A VERTICAL ROW OF CONSPICUOUS PLATES. (DICYCLIC OR MONOCYCLIC.)

*Analysis of the Genera.*

**Arms uniserial.**

*a. Radials sep*[illegible] *all around.*
 *Dicyclic.* [illegible]rabasals 5. Column pentangular . . . . . . . . . RETEOCRINUS.
 *Monocyclic.* Basals 4. Column square . . . . . . . . . . . XENOCRINUS.
*b. Radials separated only at anal side.*
 *Monocyclic.* Basals 5. Column obscurely pentangular . . . . . TANAOCRINUS.

*Geological and Geographical Distribution*

**Number of known species. Only known in America.**

| Formation. | Reteocrinidæ. | | |
|---|---|---|---|
| American. | Reteocrinus. | Xenocrinus. | Tanaocrinus. |
| Hudson River. | 3 | 2 | 1 |
| Trenton. | 1 | – | – |
| Total species . . . 7 | 4 | 2 | 1 |

*Remarks.* — This family was established to receive a little group of Lower Silurian Crinoids, distinguished from all other known forms by the irregularity and absence of definite arrangement in the interradial plates, caused by the intercalation of minute supplementary pieces. These small pieces were

introduced in the growing Crinoid in great numbers among the primary interradials and interdistichals, and between these and the basals, radials, and brachials. The interradial and interdistichal spaces throughout this group are greatly depressed, and the plates succeeding the radials folded into conspicuous ridges. This structure, combined with the more or less rudimentary character of the interposed plates, is so unique and remarkable, that all other characters, some of which in other groups are characteristic of very distinct families, appear to be subordinated to it, and we are compelled to unite under this family both monocyclic and dicyclic forms; those in which the radials are all separated, and those in which they are in lateral contact at four sides. We think that few, after seeing a large number of specimens, will doubt the propriety of this course; for the structure in question produces a habitus so distinct and predominant, that it is only by means of these characters that the three genera of this family can be separated.

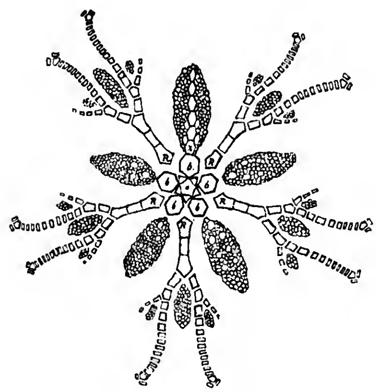


FIG. 6. *Reteocrinus Onealli.*

In our classification of 1885,* we proposed the genus *Canistrocrinus* upon two species, which according to the descriptions differed from all genera previously known. In defining the genus we relied upon the correctness of the figures; but these have proved to be misleading in some very important points, and we are compelled to withdraw it. As to "*Canistrocrinus*" *Richardsoni* (*Glyptocrinus Richardsoni* Wetherby), we are now convinced that it is a *Glyptocrinus*, and identical with *Glyptocrinus subglobosus* Meek. It has well defined interradials, and the anal plate rests *upon* the radials, and not *between* them. The other species, "*Canistrocrinus*" *Pattersoni* (*Glyptocrinus Pattersoni* S. A. Miller), may also prove to be a *Glyptocrinus*. The type specimens, which Mr. Miller was kind enough to send us for comparison, are not in a condition to make out the structure satisfactorily, being covered to a large

* Revision, Part III., p. 88.

extent by hard matrix; and we are unable to say at present to what genus they belong.

S. A. Miller, in his arrangement of the Lower Silurian Camerata in 1883,* united *Reteocrinus* and *Xenocrinus* with *Archæocrinus*, *Cupulocrinus*, *Glyptaster*, *Glyptocrinus*, and *Lampterocrinus* in one family, under the "Glyptocrinidæ." It is not clear to us upon what this classification was based, since the author did not discriminate between the presence or absence of infrabasals as a family distinction, nor between a regular or irregular arrangement of the interradials; nor did he give attention to the structure of the anal side, upon which most writers, and Miller himself, have relied for excellent family characters. In a later paper on *Glyptocrinus* and allied forms,† he states that the presence or absence of "subradial" plates, the presence or absence of "secondary radials," the structure and form of the column, and the presence or absence of a "proboscis," are the principal characters upon which "the genera of this special group" have to be separated. All of these rules are in a greater or less degree infringed by Miller himself. His "*Glyptocrinus*" *parvus* has infrabasals; his "*Glyptocrinus Fornshelli*, a pentangular stem instead of round as in the typical species. A "proboscis," such as occurs among the Actinocrinidæ, does not exist at all in this group, or at least has not been observed. Neither do we find that the proximal distichals are ever free arm plates, as Miller claims to be the case in "*Pycnocrinus*." The specimens which he refers to this genus, and which he kindly sent us for comparison, have from one to two interdistichals, and necessarily had "secondary radials."

In Miller's classification of 1889,‡ the "Glyptocrinidæ" embrace the genera *Archæocrinus*, *Glyptocrinus*, *Compsocrinus*, *Pycnocrinus*, and *Schizocrinus*, which, as we think, are representatives of almost as many families. He there makes *Xenocrinus* the type of a distinct family, refers *Glyptaster* and *Lampterocrinus* to the Glyptasteridæ, and places *Gaurocrinus*, *Reteocrinus*, *Raphanocrinus*, and *Thysanocrinus* under Gaurocrinidæ.

The Reteocrinidæ are restricted to America, where only seven species have been discovered.

* Amer. Palæoz. Foss. (ed. 2), p. 276.
† Dec., 1883; Journ. Cincin. Soc. Nat. Hist., pp. 218–219.
‡ North Amer. Geol. and Palæont., pp. 214 to 215.

## RETEOCRINUS Billings.

1859. E. Billings; Geol. Rep. Canada, Decade VI., p. 63.
1881. W. and Sp.; Revision Palæocr., Part II., p. 191 (Proceed. Acad. Nat. Sci. Phila., p. 365).
1883. P. H. Carpenter; Phil. Trans. Royal Soc. (Part III.), pp. 929-932.
1883. W. and Sp.; Amer. Journ. Sci. and Arts, Vol. XXV., pp. 255-268.
1883. S. A. Miller, ibid., pp. 105 to 113.
1885. W. and Sp.; Revision Palæocr., Part III., p. 87 (Proceed. Acad. Nat. Sci. Phila., p. 309).
1889. S. A. Miller; North Amer. Geol. and Palæont., p. 277.

Syn. *Glyptocrinus* (in part) — Hall; 1872, 24th Rep. N. York State Cab. Nat. Hist., p. 206, Plate 5, Figs. 18 & 19.

Syn. *Glyptocrinus* (in part) — Wetherby; Journ. Cincin. Soc. Nat. Hist., Vol. II., Plate 16, Fig. 1.

Syn. *Glyptocrinus* (in part) — S. A. Miller; 1881, Journ. Cincin. Soc. Nat. Hist., Vol. IV, p. 83, Plate 1, Fig. 5, and 1881, ibid. Vol. VI., p. 227.

Syn. *Gaurocrinus* (in part) — S. A. Miller; 1883, ibid. Vol. VI., pp. 228, 229.

Calyx obconical, its symmetry decidedly bilateral, interradial and interdistichal spaces profoundly depressed; the plates all along the rays distinctly folded, so as to produce strong, rounded ridges upon their outer surfaces, and deep grooves at the inner. The ridges branch upon the axillaries, and follow the distichals to the arms. Other branches proceed from the middle of the radials to adjoining basals.

Infrabasals five, variable in size; sometimes barely protruding beyond the column. Basals five, large, protuberant, hexagonal, the upper angles truncated, and the ends somewhat inflected to meet the deep depressions of the interradial spaces. Radials separated all around, sharply angular at the lower faces. Costals two to three; their axillaries closely resembling the radials, but angular above instead of below. Distichals numerous; all, or nearly all of them, take part in the calyx, and the upper ones retain the form of free arm joints. The proximal pinnule occurs on the second distichal. Arms ten at their origin, but generally bifurcating; composed of rectangular or slightly cuneate pieces. The interradial and interdistichal spaces filled by primary and secondary plates; the latter very minute, indefinitely arranged, ill-formed, and interposed between the others, and along the sides of the basals, radials, and brachials. The anal interradius wider, and longitudinally divided into two equal parts by a row of very prominent anal plates, which lie in a straight line from the basals to the anal opening. Ventral disk depressed convex, composed throughout of minute irregular pieces, which form a continuation from the interbrachials and interdistichals. Ambulacra subtegminal: Anal opening excentric, at the top of a small protuberance.

Column large, pentagonal; the axial canal of medium size.

*Distribution.* — Age of the Trenton and Hudson river groups. Restricted to America.

*Remarks.* — According to Billings, the calyx of *Reteocrinus stellaris*, the type of the genus, consists of a reticulated skeleton, composed of incomplete or rudimentary plates, each consisting of a central nucleus, with three to five stout processes radiating from it. Of such plates he describes three rings of five each, corresponding in position with infrabasals, basals, and radials of other Crinoids, and he states that the genus in general structure agrees with *Cyathocrinus*, *Dendrocrinus*, and allied forms.

It would seem at first sight that this description does not apply to "*Glyptocrinus*" *Oncalli* and the other species that have been referred to this genus, as they have numerous interbrachials and interdistichals which Billings failed to notice. These plates, however, are actually present in the type specimens, having been exposed by additional cleaning. Looking at *Reteocrinus Oncalli* in its usual preservation, with its deep interradial areas covered by matrix, it corresponds well with the original description. The specimens in that state seem to have but three rings of plates in the calyx, and free brachials from the radials up.

Miller refers to *Reteocrinus* only Billings' two typical species, placing the other three under *Gaurocrinus*. We cannot discover any ground for generic separation of the Ohio and Canada species. It is true *Reteocrinus stellaris* has a third costal, but Miller himself did not attach much importance to this character, for he grouped *Reteocrinus fimbriatus* with but two costals, along with *R. stellaris*, which has three.

In amending the genus *Reteocrinus* in 1881,* we referred to it the following species: *Glyptocrinus Baeri* Meek, *Glyptocrinus cognatus* Miller, *Reteocrinus fimbriatus* Billings, *Reteocrinus gracilis* Wetherby, *Glyptocrinus Oncalli* Hall, *Glyptocrinus Richardsoni* Wetherby, and *Reteocrinus stellaris* Billings. We afterwards † withdrew *Reteocrinus Baeri*, which we found to be a *Xenocrinus*, and *Reteocrinus Richardsoni*, which we placed under *Canistrocrinus;* and we added *Gaurocrinus magnificus* S. A. Miller. *Reteocrinus cognatus* is probably a large *R. Oncalli*, and *R. gracilis* a synonym of *Ptychocrinus parvus*.

* Revision, Part II., p. 192.
† Revision, Part III., p. 96.

**Reteocrinus stellaris** Billings.

*Plate IX. Figs. 3a, b, c.*

1859. E. Billings; Geol. Rep. Canada, Decade IV., p. 64, Plate 9, Figs. 4*a, b, c*.
1877. S. A. Miller; Catal. Amer. Palæoz. Foss., p. 90.
1881. W. and Sp. Revision Palæocr., Part II., p. 193.
1889. S. A. Miller; North Amer. Geology and Palæont., p. 277.

Calyx proportionally larger than in any other species of the genus, embracing all the distichals and portions of the palmars.

Infrabasals and basals unusually large; the former projecting distinctly beyond the column, each plate forming a good-sized pentagon. Basals heptagonal, slightly truncated and folded inward at the upper ends; four of them of equal size, that facing the anal side larger, and the truncation wider. The surface of the basals is marked by prominent keel-like processes, meeting in the centre of the plates; one of these proceeds to the radials and costals, two others to the infrabasals. At the sides of the processes there are deep depressions, five of them in a radial direction, formed by the inflection of the lower angles of the radials and the upper lateral margins of the basals; five others, somewhat smaller, triangular in outline and interradial, by the basals and infrabasals. The posterior basal, at its upper face, has three ridges instead of two, of which the median one is continuous with that formed by the anal plates. Radials about one half longer than the costals. Costals three; the first and second quadrangular, the third pentangular. Distichals five to seven or more, decreasing in width upwards, the upper ones taking the form of free arm plates. Above the distichals are two more divisions, but only a few of the palmars take part in the calyx. The arms are extremely short, and taper rapidly; they are composed of rather long, quadrangular joints. Interbrachial and interdistichal areas profoundly depressed, paved by numerous irregularly arranged and ill-formed pieces, with a slightly stellate surface. Anal interradius twice as wide as the others; divided by a longitudinal row of anal plates, somewhat narrower than the costals, but resembling them in height and curvature. Construction of tegmen, position of anal opening, and arrangement of pinnules unknown. Column obscurely pentangular, at the upper end composed of very thin, knife-like joints.

*Horizon and Locality.* — Trenton limestone; City of Ottawa, Ontario, Canada.

Our figures were made from the *type* specimens in the Canada Survey Museum.

### Reteocrinus fimbriatus Billings.

*Plate IX. Fig. 4.*

1859. E. Billings; Geol. Rep. Canada, Dec. IV. p. 65, Plate 9, Fig. 3.
1877. S. A. Miller; Catal. Amer. Palæoz. Foss., p. 90.
1881. W. and Sp.; Revision Palæocr. Part II., p. 193.
1883. W. and Sp.; Amer. Journ. Sci., Vol. XXV., p. 266.
1889. S. A. Miller; North Amer. Geol. & Palæont., p. 277.

A small species of the type of *Reteocrinus magnificus.* Dorsal cup to the top of the costals subpyramidal; slightly more spreading from there upward. The plates forming the rays rounded, and elevated conspicuously above the interradial spaces.

Infrabasals small, their upper angles and the adjoining lower angles of the basals depressed into small pits surrounding the column. Similar pits are formed in a radial direction by the basals and lower margins of the radials. Costals two, as large as the radials. Distichals eight or more, narrower than the costals, the lower one longer than wide, the length of the succeeding ones gradually decreasing upwards. Six of them apparently are included in the calyx, the others free arm plates. The upper distichal is axillary, and supports two arms, one of which remains simple, while the other bifurcates once more. The arms decrease but little in size; they are cylindrical, composed of rather long pieces, quadrangular in outline, with nearly parallel faces. Pinnules decidedly tapering to their distal ends. Interradial spaces deep, paved by a large number of very small, slightly convex pieces, without definite arrangement. There is generally but one plate in contact with the basals, but its outlines are very irregular, and that is still more the case with the succeeding plates, and the numerous interdistichals. Form of ventral disk, and construction of the anal side unknown. Column at its upper end sharply pentagonal, with re-entering angles.

*Horizon and Locality.* — Hudson River group; Charleton Point; Anticosti. — *Type* in the Canada Survey Museum.

### Reteocrinus Nealli (Hall).

*Plate IX. Figs. 1a–f.*

1872. *Glyptocrinus Nealli* — Hall; 24th Rep. N. Y. State Cab. Nat. Hist, p. 206, Plate 5, Figs. 18 & 19.
1873. *Glyptocrinus Onealli* — Meek; Geol. Rep. Ohio, Palæont., I., p. 34, Plate 2, Figs. 3*a*, *b*, *c*.
1881. *Reteocrinus Onealli* — W. and Sp.; Revision Palæocr., Part II., p. 193.
1882. *Glyptocrinus Nealli* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 37.
1883. *Reteocrinus Onealli* — W. and Sp.; Amer. Journ. Sci., Vol. XXV., p. 260.
1883. *Gaurocrinus Nealli* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., p. 229.

1885. *Reteocrinus Oneali* — W. and Sp.; Revision Palæocr., Part III., p. 86.
1889. *Gaurocrinus Nealli* — S. A. MILLER; North Amer. Geol. & Palæont., p. 247.
Syn. *Glyptocrinus cognatus* — S. A. MILLER; 1881, Cincin. Journ. Nat. Hist., Vol. IV., p. 75, Plate 1, Figs. 5, 5*a*.
Syn. *Gaurocrinus cognatus* — S. A. MILLER; 1881, Cincin. Journ. Nat. Hist., Vol. VI., p. 229.
Syn. *Reteocrinus cognatus* — W. and Sp.; 1881, Revision Palæocr., Part II., p. 193.

Calyx obconical; interradial and interaxillary spaces deeply depressed, producing a pentagonal outline below the distichals, and decagonal above them.

Infrabasals small, but projecting beyond the column. Basals large, their lateral margins deeply impressed, forming an elongate pit in which the upper angles of the infrabasals and the lower angles of the radials are involved. The radials, costals, and lower distichals are folded abruptly inward, their sides extending to the bottom of the interradial and interdistichal spaces, leaving a very narrow surface exposed, not more than the width of the arms. Distichals ten to fourteen, of which six to seven are located within the calyx walls, the others free. Of the fixed plates, the three or four proximal ones are larger and especially longer than the succeeding ones, which are nearly as short as the free plates. A second bifurcation takes place in the free arms, giving twenty arms to the species. Arms long, cylindrical, gradually tapering, and composed of short, wedge-formed pieces. The first pinnule, which is given off from the second distichal, is more erect, and considerably stouter than any of the rest. The second pinnule, which occurs on the opposite side at the fourth plate (the third bears no pinnule), is smaller than the first, but larger than the third, which is of the ordinary size. The three proximal pinnules are incorporated into the calyx, the succeeding ones free. Interbrachials and interdistichals very numerous, exceedingly small, and of very irregular form and size; the marginal pieces, as a rule, being smaller than the others. Anal side marked by a conspicuous median ridge. Tegmen low-hemispherical, decagonal in outline; the spaces overlying the food grooves slightly elevated. Anal opening excentric, almost marginal, placed in the middle of a small protuberance. Column pentangular, the outer faces slightly impressed; composed alternately of thin and somewhat thicker plates, the latter protruding considerably beyond the others.

*Horizon and Locality.* — Upper part of the Hudson River group; Warren Co., O.; rare at Cincinnati.

*Type* specimen formerly in the collection of J. Kelley O'Neall, now in the collection of Wachsmuth and Springer.

*Remarks.* — The peculiarity that the smallest interradials are marginal and lie next to the radials and basals, instead of diminishing in size upward, as is usually the case, leads to the conclusion that these plates were introduced between some of the older pieces, and are secondary plates which cannot be homologized with the primary interradials of the Actinocrinidæ. The structure is well shown in our figure, Plate IX. Fig. 1*f*, which represents the inner floor of a fine specimen in which the arrangement of the primary interradials is very little disturbed, being 1, 2, 3, all of them isolated and surrounded by small supplementary pieces. We shall discuss this subject further in our remarks upon *Xenocrinus penicillus* and *X. Baeri*.

We have had no opportunity to examine the type specimen of *Glyptocrinus cognatus* S. A. Miller, in the collection of Dr. R. M. Byrnes of Cincinnati, but from the description and the figure we are strongly inclined to regard it as a large specimen of *Reteocrinus Oncalli*, and not a variety of that species, as suggested by Miller.

### Reteocrinus magnificus (Miller).

*Plate IX., Fig. 2.*

1883. *Gaurocrinus magnificus* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 230, Plate 11, Fig. 2.
1885. *Reteocrinus magnificus* — W. and Sp.; Revision Palæocr., Part III., p. 94.
1889. *Gaurocrinus magnificus* — S. A. Miller; North Amer. Geol. and Palæont., p. 247.

A larger species than *Reteocrinus Oncalli*. Calyx subovoid; section pentangular; the interradial and interdistichal spaces deeply depressed; the radial ridges broad, flattened at their upper faces, and branching from the middle of the radials to adjoining basals.

Infrabasals small, almost covered by the column. Basals of medium size, somewhat convex, their upper ends inflected toward the impressed interradial areas, the interbasal suture lines deeply grooved, and forming with the lower end of the radials a lozenge-shaped concavity. Radials a little narrower at the top than at the bottom. Costals two, narrow, as long as the radials, and without lateral extensions. Distichals very variable in number, from two to fifteen, the three or four lower ones almost as large as the costals. When there are but two distichals, which is apparently exceptional, there is an additional bifurcation in the calyx; while in the other cases there is only one more bifurcation, which takes place in the free arms, and the second distichals support a very large pinnule. Arms stout, rounded and constructed of extremely short, slightly convex, cuneate pieces. Pinnules composed of five or more joints; long, slender, and not in lateral contact. The first pinnule is borne upon the second distichal, above which every joint, the axillaries excepted, is pinnule-bearing. Interradial areas more substantial than in the preceding species, the plates stouter, and the median portions rather convex than concave. Each area contains from twenty-five to thirty pieces, some larger than others, of all possible shapes, and indiscriminately arranged. The construction of the anal side is not known. The interdistichal areas apparently extend to the top of the fifth distichals, are comparatively flat, and composed of similar pieces to those of the interradial spaces. Construction of disk and anus unknown. Column near the calyx distinctly pentangular; the nodal joints longer, slightly projecting and rounded at the margin; the internodal ones shorter, and provided with sharp edges.

*Horizon and Locality.* — Hudson River group, Warren Co., Ohio.

The *type* specimen now in the collection of Wachsmuth and Springer.

## XENOCRINUS S. A. MILLER.

1881. S. A. MILLER; Journ. Cincin. Soc. Nat. Hist., Vol. IV., p. 72.
1881. W. and SP.; Revision Palæocr., Part II., p. 184.
1883. W. and SP.; Amer. Journ. Sci., Vol. XXV., p. 266.
1884. P. H. CARPENTER; Philos. Trans. Royal Soc., Part III., p. 930.
1885. W. and SP.; Revision Palæocr., Part III., p. 94.
1885. W. and SP.; Proceed. Acad. Nat. Sci. Phila., p. 317.
1889. S. A. MILLER; North Amer. Geol. and Palæont., p. 287.

*Xenocrinus* resembles *Reteocrinus*, but is without infrabasals. Basals four, forming a low cup, which is decagonal at the upper end; five of its sides supporting the five radials, the five others the interradial and anal plates. This arrangement gives to the basals, owing to their abnormal number, a very irregular form, no two of the plates being alike. Radials generally a little larger than the costals. Costals two, the sides bending abruptly inward and forming highly elevated ridges; the distichals to about the fifth or eighth plate form part of the calyx. The lower of these plates are larger, and more or less resemble the costals, while the upper ones are more like free arm plates. Arms ten, simple, rather stout; composed of very short cuneiform pieces, which at the tips of the arms slightly interlock.

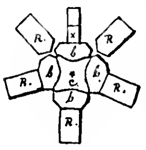


FIG. 7.

Interradial spaces deeply impressed; composed of numerous minute pieces without definite arrangement; they rest upon the basals, separating the rays from their bases up. Anal interradius wider than the four others; divided longitudinally by a row of folded plates, which like the radials have a prominent ridge upon the outer surface, and a groove at the inner floor. The ridge ends in a small protuberance containing the anal opening, which points upwards. Interdistichal spaces also deeply depressed, and filled by irregular, minute plates, which like those between the main rays pass imperceptibly into the disk. Ventral disk comparatively flat, composed throughout of very small pieces; orals being unrepresented, and the disk ambulacra subtegminal.

Column quadrangular, with pentangular central canal, the angles of which are directed interradially.

*Distribution.* — This genus, so far as known, is limited to the upper part of the Hudson River group of Ohio.

*Type.* — *Xenocrinus penicillus* Miller.

*Remarks.* — We place in this genus *Glyptocrinus Baeri* Meek, which, as we have discovered, has a quadrangular stem and four basals. *Xenocrinus* is the only monocyclic genus in which interradials come in contact with the basals at all sides, but we doubt if its interradials separated the rays as completely as in the case of the Rhodocrinidæ. In a specimen of *X. Baeri* from the collection of Mr. I. H. Harris (Plate IX. Fig. 5*c*), in which portions of the inner floor are exposed, it is plainly seen that the lower ends of adjoining radials touch each other, and after a careful study of the structure we are inclined to believe that the small accessory pieces, which seem to separate the radials, rest upon the lower outer margins of the plates, and not between the plates.

### Xenocrinus penicillus Miller.

*Plate IX. Figs. 6a, b.*

1881. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. IV., p. 72, Plate 1, Fig. 3; and ibid., p. 176, Plate 4, Fig. 6.

1883. W. and Sp.; Amer. Journ. of Sci., Vol. XXV., p. 266, and 1885, Revision Palæocr. Part III., p. 96.

A small species. Calyx elongate, once and a half as high as wide, obconical at the lower end, then rising almost vertically to the free arms; the radials and brachials highly elevated, folded lengthwise with rounded back; the interradial spaces deeply impressed, the plates somewhat nodose.

Basals forming a small basin, which at the bottom is slightly excavated for the reception of the column. Radials and costals of nearly equal size, one third longer than wide, their lateral faces distinctly convex, so as to give to the sides a sort of scalloped appearance. Distichals free from the ninth or tenth plate; the four or five lower ones elongate, in form and size resembling the costals; the succeeding ones gradually decreasing in length; and the upper ones as short as the free arm plates. Arms ten, apparently short; composed of low cuneate pieces with somewhat rounded outer edges. The first pinnule starts from the second distichal; it is stronger than the others, and, like the three or four succeeding ones, incorporated into the calyx. The free pinnules are more slender and longer; they consist of six to seven joints, twice as long as wide. Interradial spaces deepening toward the middle, and deepest in their upper portions. They are composed of a very large number of minute pieces, are irregularly arranged, tuberculous and slightly stellate. Similar plates fill up the spaces between the distichals. Anal interradius wider; divided by a longitudinal row of fifteen or more large anal plates, which in form and size resemble the lower brachials, and their sides are scalloped in a similar manner. The row terminates in a small protuberance near the margin of the disk, which contains the anal opening. Ventral disk hemispherical, pentangular in outline, the surface slightly elevated in the direction of the food grooves; composed of hundreds of minute pieces; the ambulacra subtegminal. Column quadrangular, its sides distinctly concave. Axial canal pentangular.

*Horizon and Locality.* — Hudson River group; Warren Co., O.

*Types* in the collection of Mr. I. H. Harris of Waynesville, O.

*Remarks.* — Among the specimens examined, there is a very interesting small one, in which the interradials do not touch the basals. In this specimen it is most remarkable how the interradials vary in size. Three of them are tolerably large, but they are isolated from each other, and from the radials and basals, by numerous small, almost microscopic pieces, smaller than the corresponding plates in more mature specimens. The larger plates occupy approximately the position of the first and second row of interbrachials in the Actinocrinidæ, and undoubtedly represent them, being pushed out of position by the development and intercalation of supplementary pieces.

### **Xenocrinus Baeri** (Meek).

*Plate IX. Figs. 5a–d.*

1872. *Glyptocrinus Baeri* — Meek; Amer. Journ. Sci., Vol. III. (3d ser.), p. 260.
1873. *Glyptocrinus Baeri* — Meek; Geol. Rep. Ohio, Palæont., Vol. I., p. 37, Plate 2, Fig. 1.
1880. *Glyptocrinus baeri* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. III., Plate 7, Fig. 4.
1881. *Reteocrinus Baeri* — W. and Sp.; Revision Palæocr., Part II., p. 193.
1883. *Reteocrinus Baeri* — W. and Sp.; Amer. Journ. Sci., Vol. XXV., p. 266.
1883. *Glyptocrinus baeri* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. IV., p. 226.
1885. *Xenocrinus Baeri* — W. and Sp.; Revision Palæocr., Part III., p. 96.
1889. *Xenocrinus baeri* — S. A. Miller; North Amer. Geology and Palæont., p. 288.

Dorsal cup higher than wide; subovoid; depressed at the interradial spaces, but not so much so as in *X. penicillus*; cross-section pentangular.

Basals small, only their upper angles visible in a side view. Radials and costals elongate, formed into conspicuous rounded ridges, which occupy almost the entire width of the plates. Distichals free from the fifth or sixth plate; the two proximal ones as large as the costals, the third somewhat shorter, and the upper ones but little longer than the free plates. Arms ten, simple, long, rather stout; composed of very short, transverse joints, with slightly convex outer faces. The lower arm joints rectangular, followed by cuneate pieces, which slightly interlock. Interradial areas deepest in the middle; composed of numerous very small, convex pieces, with a somewhat corrugated surface. Anal side divided by a longitudinal row of anal plates, shaped like the radials and costals. Ventral disk low-hemispherical; plates very minute; the position of the anus unknown. Column quadrangular, with obtuse angles; the joints extended outward into long knife-like edges.

*Horizon and Locality.* — Hudson River group; Warren Co., O., and Richmond, Ind.

The specimens figured are from the Collection of Wachsmuth and Springer, and that of I. H. Harris, Esq., of Waynesville, O.

### **TANAOCRINUS** (nov. gen.), W. and Sp.

(ταναός, slender; κρίνον, a lily).

Resembling *Reteocrinus*, but without infrabasals, and the radials in lateral contact except at anal side. Symmetry decidedly bilateral. Arms long and slender.

Basals small; the posterior one truncated at the upper end, and followed by a large anal plate. Costals two, narrower than the radials, and folded like arm plates. Distichals numerous, for the most part incorporated into the calyx. Arms branching once or twice beyond the calyx.

Interradial and interdistichal areas deeply depressed, filled by numerous minute, irregular pieces. Anal side wider than the other four, divided by a median longitudinal row of large anal plates, folded like the costals. Structure of the disk and position of the anus unknown. Column round or obscurely pentagonal.

*Distribution*, etc. — Restricted to the Hudson River group of America.

*Type* of the genus: — *Tanaocrinus typus* W. and Sp.

**Tanaocrinus typus** (nov. spec.), W. and Sp.

*Plate IX. Figs 7a, b, c.*

A small and slender species. Calyx elongate; broadly truncate at the lower end; plates without ornamentation.

Basals five, plainly visible in a side view; forming a short cup, which is slightly excavated at the bottom. The upper faces in four of the plates sharply angular, that of the posterior side narrowly truncate. Radials the largest plates of the calyx, much narrower at the top than at the bottom, rounded at the lower face. They are connected laterally, forming a wide and deep notch for the reception of the interradials, except at the anal side where the first anal plate rests directly upon the basals. Costals two, as long as the radials but narrower; folded and elevated in the middle, the lateral margins on a level with the interradials. Distichals seven to eight; all, or nearly all of them, incorporated into the calyx; the lower ones as long as the costals, but a little narrower; the upper ones gradually growing shorter, and taking the form of free arm joints. Palmars twelve or more, all of them free. The arms branch two or three times; they are long, cylindrical, and taper gradually to the tips, where they become very delicate and thread-like. They are composed of short, cuneate pieces which do not interlock. The first pinnule is given off from the second distichal; it is more than twice as large as any of the others, and it, as well as the three or four succeeding ones, is enclosed in the calyx. Interradial and interdistichal spaces deeply depressed, the plates very small and without definite arrangement. Anal side twice as wide as the other four, and divided longitudinally by an anal ridge of five to six large plates, which closely resemble the radials and costals. The first anal plate, which rests upon the basals, is nearly as large as the radials, and like them narrower above than below; the succeeding ones are a little smaller than the costals. Ventral disk not visible in the specimens. Column comparatively large and obscurely pentagonal, the nodal joints larger, and with slightly undulating edges.

*Horizon and Locality.* — Upper part of the Hudson River group, Warren Co., O.

The *type* specimens, which are in our collection, were presented to us by Dr. S. S. Scoville of Lebanon.

# THYSANOCRINIDÆ W. and Sp.

## (GLYPTASTERIDÆ W. and Sp. 1885).

DICYCLIC. LOWER BRACHIALS AND INTERBRACHIALS FORMING AN IMPORTANT PART OF THE DORSAL CUP; INTERBRACHIALS WELL DEFINED. RADIALS IN CONTACT EXCEPT AT THE POSTERIOR SIDE, WHERE THEY ARE SEPARATED BY AN ANAL PLATE.

*Analysis of the Genera.*

**Infrabasals 5.**

A. ANAL SIDE SLIGHTLY ELEVATED. ANUS WITHOUT A TUBE.
- 1. *First anal plate followed by three plates.*
  - a. *Dorsal cup deep.*
    - Arms uniserial, 10 . . . . . . . . . . . . . . . PTYCHOCRINUS.
    - Arms biserial, erect, ten to twenty . . . . . . . . . THYSANOCRINUS.
  - b. *Dorsal cup short, almost flat.*
    - Arms pendent, posterior oral and radial dome plates spiniferous . . . . . . . . . . . . . . . . HYPTIOCRINUS.
- 2. *All interbrachial spaces having a single large plate* . . . . IDIOCRINUS.

B. ANAL SIDE BULGING. ANUS AT THE END OF A TUBE.
- 1. *First anal plate followed by three small plates.*
  - *Rays produced into tubular extensions.*
    - Infrabasals large . . . . . . . . . . . . . . . LAMPTEROCRINUS.
- 2. *First anal plate followed by three large plates.*
  - *Rays branching in the regular way.*
    - Infrabasals small . . . . . . . . . . . . . . . . SIPHONOCRINUS.

*Geological and Geographical Distribution.*

**Number of known species.**

(Open figures indicate American, those marked ( ), European.)

| Formation. | | | | Thysanocrinidæ. | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| General. | | American. | Approximate European Equivalents. | Ptychocrinus. | Thysanocrinus. | Hyptiocrinus. | Idiocrinus. | Lampterocrinus. | Siphonocrinus. |
| Silurian. | Upper | Niagara. | Dudley Gotland. | | 5 (7) | 1 | 4 | 1 | 3 |
| | Lower | Huds. River. | | 2 | | | | | |
| Total species . . . 23 | | | | 2 | 5 (7) | 1 | 4 | 1 | 3 |

*Remarks.* — We have changed the name Glyptasteridæ, which we proposed in 1885,* into Thysanocrinidæ, because we found it necessary to give up Hall's genus *Glyptaster*. We also discard *Dimerocrinus* Phillips, and *Eucrinus* Angelin, and arrange the species of both under *Thysanocrinus*.† That Phillips' figures of *Dimerocrinus* were insufficient for generic identification, is shown by the fact that the genus has been referred by Roemer and Dujardin

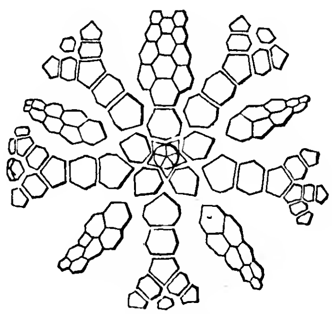


FIG. 8. *Thysanocrinus.*

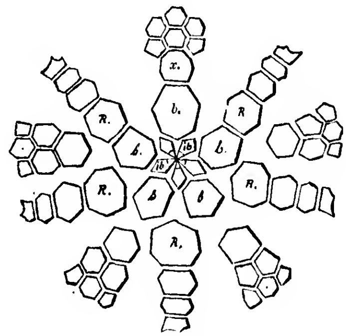




FIG. 9. *Lampterocrinus.*

and Hupé to the Cyathocrinidæ, while Zittel made it the type of a monocyclic family. *Glyptaster* and *Eucrinus* were placed by Zittel along with *Lampterocrinus*, *Archæocrinus*, and *Glyptocrinus* under the Glyptocrinidæ; in which he was followed by S. A. Miller, who added *Reteocrinus* and *Xenocrinus*, but withdrew them again in 1889. *Thysanocrinus* was placed at first by both authors under the Rhodocrinidæ, from which afterwards Miller removed it to the Glyptasteridæ.

The Thysanocrinidæ have their closest affinities with the Rhodocrinidæ. Both are dicyclic, but in the Rhodocrinidæ the interradials at all five sides are in contact with the basals, thus, as a general rule, completely isolating the radials laterally; while in the Thysanocrinidæ the radials are in contact all around except at the posterior side, where the anal plate overlies the basals. This bilateral symmetry in the arrangement of the plates of the dorsal cup is accompanied by a marked asymmetry in the general form of the calyx, and especially of the ventral disk, which is more or less enlarged

* Revision, Part III., p. 89.

† See under *Thysanocrinus*.

posteriorly in most of the species of the Thysanocrinidæ. In the new genus *Idiocrinus*, in which there is but one interbrachial plate to each of the five sides, there is no special anal plate, and the posterior interradial, which is larger and rests upon the basals, serves as the anal.

The family is confined to the Silurian, and is composed of six genera, with twenty-three species, of which sixteen are from America, and seven from the upper Silurian of England and Sweden.

## THYSANOCRINUS Hall.

1836. *Dimerocrinus* — Phillips; Murchison's Silur. Syst., p. 674, Plate 17, Figs. 4 and 5.
1841. *Dimerocrinus* — Müller; Monatsber. Berlin. Akad. d. Wissensch., p. 208.
1850. *Dimerocrinus* — d'Orbigny; Prodrôme I., p. 46.
1852. *Glyptaster* — Hall; Palæont. N. York, Vol. II., p. 187.
1852. *Thysanocrinus* — Hall; Ibid. p. 190.
1852. *Dimerocrinus* — d'Orbigny; Cours élément., Part II., p. 142.
1855. *Dimerocrinus* — Roemer; Lethæa Geognost. (Ausg. 3), p. 237.
1857. *Thysanocrinus* / *Dimerocrinus* — Pictet; Traité de Paléont., Vol. IV., pp. 317 and 318, Plate C, Fig. 13.
1859. *Dimerocrinus* — Murchison; Siluria (3d ed.), p. 535, Plate 13, Figs. 4 and 5.
1862. *Thysanocrinus* / *Dimerocrinus* — Dujardin and Hupé; Hist. Natur. des Zoophytes, pp. 128 and 131.
1863. *Glyptaster* — Hall; Trans. Albany Inst., Vol. IV., p. 202.
1873. *Dimerocrinus* — Salter; Catal. Geol. Museum, Cambridge, p. 120.
1878. *Glyptaster* — Hall; 28th Rep. N. Y. State Mus. Nat. Hist. (ed. 2), pp. 131 and 133.
1878. *Eucrinus* — Angelin; Iconogr. Crin. Suециæ, p. 24.
1879. *Thysanocrinus* / *Glyptaster* / *Dimerocrinus* / *Eucrinus* — Zittel; Handb. d. Palæont., Vol. I., pp. 368 and 375.
1881. *Glyptaster* / *Dimerocrinus* / *Eucrinus* — W. and Sp.; Revision Palæocr., Part II., pp. 193 to 199. Also ibid., Part III., p. 101.
*Thysanocrinus* (syn. of *Dimerocrinus*).
1889. *Glyptaster* / *Eucrinus* / *Thysanocrinus* — S. A. Miller; N. Am. Geol. and Palæontology.

Syn. *Dimerocrinus* Phillips.
Syn. *Glyptaster* Hall.
Syn. *Eucrinus* Angelin.

Calyx subglobose, urn or bell-shaped; the rays marked by a more or less conspicuous ridge; the general surface of the plates smooth or variously ornamented. Infrabasals five, small, barely protruding beyond the column, or entirely hidden by it. Basals five, four of them equal, angular above; the fifth truncated, and supporting a large anal plate. Radials considerably larger than the costals, their lower sides distinctly angular, the lateral faces comparatively short. Costals two. Arms ten or twenty, rather strong and biserial; pinnules long. The first interbrachial large, resting upon the sloping upper corners of two radials and against the costals. There are two plates in the second range, and often smaller ones above, which connect with the plates of the disk. The anal side considerably wider; the first plate large, hexagonal, resting upon the posterior basal; the second range containing three plates. Some species have an uninterrupted row of anal plates all the way to the anal opening. Interdistichals generally represented and rather large. Structure of the ventral disk and position of the anus only known in one species. (See *Thysanocrinus inornatus*) column round or obtusely pentangular.

*Distribution.* — Restricted to the Niagara group of America, the Wenlock group of England, and its equivalent in Sweden.

*Type* of the genus. — *Thysanocrinus liliiformis* Hall.

*Remarks.* — We have reduced *Dimerocrinus*, *Glyptaster*, *Thysanocrinus* and *Eucrinus* to one genus, finding it utterly impossible to distinguish them generically. There is some doubt, however, by what name the genus should be known. The name *Dimerocrinus* was applied by Phillips to two species from Dudley, *D. decadactylus* and *D. icosidactylus.* Both were figured but not described, and the figures were poor and did not reveal the characteristics of the genus. A meagre description was given by Müller, who mentioned "a pelvis," succeeded by $3 \times 5$ radials, and two series of arm plates. D'Orbigny described it with three basals, succeeded by three rings of plates. From such vague and incorrect descriptions, Hall could not suspect that a species with five basals and infrabasals would be generically identical with species described as possessing three basals and no infrabasals, and we believe he was justified in proposing for his species a new genus. Pictet and Dujardin and Hupé, who accepted both genera, placed them near together. Zittel, however, even refers them to distinct families. We were the first to point out the generic identity of *Thysanocrinus* with the forms which are held to represent *Dimerocrinus decadactylus* and *D. icosidactylus*, but discriminated in favor of the older name *Dimerocrinus*, which we now think was scarcely fair to Hall. Besides, we accepted *Glyptaster* and *Eucrinus*, though with some hesitation, making the latter a subgenus of the former. The name *Glyptaster* was proposed for a solitary specimen. described as *G. brachiatus*, in which all the plates of the calyx were obscured by matrix, but showing ten spreading biserial arms without visible pinnules, and it was principally upon the absence of pinnules, it seems, that the genus was founded. Through the kindness of Prof. Whitfield we were permitted to examine this specimen, and to free it from the surrounding matrix, when we found the pinnules well developed, and the plates of the calyx arranged as in the typical form of *Thysanocrinus* (Plate XVIII. Fig. 4).

*Eucrinus* was separated from *Thysanocrinus* on account of having twenty arms, as against ten in the latter. A bifurcation or two, more or less, cannot be regarded as a good generic distinction, and we therefore place Angelin's species: *Eucrinus interradialis, E. lævis, E. ornatus, E. quinquangularis* and *E. speciosus*, under *Thysanocrinus;* but not his *E. minor* or *E. venustus*, which are types of a different genus. *Rhodocrinus quinquelobus* Schultze, which we formerly placed under *Eucrinus*, is a Rhodocrinoid. *Thysanocrinus* (*Rhodocrinus*) *microbasilis*, and *Th.* (*Rhodocrinus*) *pyriformis* Billings, have been referred by us to *Archæocrinus; Th. immaturus* to *Idiocrinus*. *Thysanocrinus aculeatus* and *Th. canaliculatus* are named from arm fragments. *Dimerocrinus oligoptilis*, and its synonym *D. aptilis* from Russia, belong to *Taxocrinus*. *Glyptaster pentangularis* Hall is described from internal casts, and is, to say the least, a doubtful species. *Cyathocrinus waldronensis* S. A. Miller (*Dimerocrinus waldronensis* W. and Sp.) cannot be identified from the description and figure, but may be a young *Thysanocrinus inornatus*. Neither can *Glyptaster Egani* S. A. Miller, which is described from a fragmentary specimen.

### **Thysanocrinus liliiformis** Hall.

*Plate XVIII. Fig. 4.*

1852. *Thysanocrinus liliiformis* — Hall; Palæont. N. York, Vol. II., p. 188, Figs. 1*a–f*.
1881. *Dimerocrinus liliiformis* — W. and Sp.; Revision Palæocr., Part II., p. 199, and Proceed. Acad. Nat. Sci. Phila., p. 373.
1889. *Thysanocrinus liliiformis* — S. A. Miller; N. Amer. Geol. and Palæont., p. 286.

Form of calyx apparently globose (the exact shape cannot be ascertained owing to the somewhat crushed condition of the type specimen); the plates ornamented by elongate nodes or interrupted striæ, which give to the surface a corrugated appearance.

Infrabasals small, scarcely visible in a side view. Basals nearly as large as the radials; that of the anal side even larger and broadly truncate, the others angular above. All plates in a radial direction provided with a low, almost flat, obscure ridge, following the median line of the plates, and covered by longitudinal striæ which are continued into the arms. Radials wider than long, but slightly angular below; their lateral faces short, leaving a deep notch for the reception of the first interbrachials. Costals about of equal size, considerably smaller than the radials. Arms ten, rather stout, the two lower plates, which are included in the calyx, longer than the free plates; the latter short, arranged in two series, with a few cuneate interlocking joints at the proximal end. Pinnules long, closely packed; composed of about six remarkably long joints, which are thickest at the ends. First interbrachials as large as the radials; succeeded by two much smaller plates, and a few still smaller ones above. Anal plate large, resting upon the truncated basal; succeeded by three plates in the second row. Structure of disk and position of anal opening unknown. Column round, strong, the nodal joints wider and longer, rounded at their edges.

*Horizon and Locality.* — Niagara group; Lockport, N. Y.

*Type* in the Museum of Cornell University at Ithaca.

### **Thysanocrinus inornatus** (Hall).

*Plate XVIII. Figs. 6a, b, c, d,* and *XIX. Fig. 5.*

1863. *Glyptaster inornatus* — Hall; Trans. Alb. Inst., Vol. IV., p. 205; also 28th Rep. N. Y. State Mus. Nat. Hist. (1879, Ed. II., p. 134), Plate 14, Figs. 1–6; also 11th Rep. Geol. Surv. Indiana, 1881, p. 263, Plate 13, Figs. 1–6.

1881. *Glyptaster inornatus* — W. and Sp.; Revision Palæocr., Part II., p. 196.

Calyx somewhat urn-shaped, the sides slightly convex; cross-section at the top of the costals pentagonal, the angles corresponding to the rays; across the distichals decagonal.

Infrabasals very minute, only the extreme points of the plates visible beyond the column.* The ornamentation consists of single series of broad, ill-defined radiating ridges or elevations. Some of the more prominent ones follow the median line of the rays; while others take a lateral direction, radiating from the centre of the plates to the margins, where they meet with similar ridges from the interbrachials and basals.

Basals large, their lower margins thickened and expanded into nodes — one to each plate — which stand on a level with the top stem joint, and form a marked pentalobate rim around it. Radials larger than the basals, and wider than long. First costals considerably smaller and quadrangular,

* Prof. Hall described the "basals" — the infrabasals of modern terminology — as "much developed, distinctly pentangular, with a double or triple node on each plate, and spreading beyond the column." From this description we suspect that the author took the nodes at the lower end of the *basals* for plates, and overlooked the small infrabasals which are rarely observed. We draw attention to this, because Hall, in comparing this species with his "*Glyptaster*" *occidentalis,* makes "the greater development of the basal plates" a specific distinction.

the second about as large as the first. Distichals four in the calyx, the rows separated by from one to three interdistichals. The second distichal bears a pinnule, which is for the most part incorporated into the calyx. Arms unknown. Interbrachial spaces deeply depressed, so as to give to the calyx at the arm bases a decidedly lobed appearance; the first plate nearly as large as the radials, the two of the second row slightly smaller, followed by much smaller ones in the third and fourth rows. Anal interradius considerably wider, more depressed, and longitudinally divided by a row of elongate, hexagonal anal plates, which form a conspicuous, rounded ridge reaching to the anal opening. The plates at each side of the ridge consist of about the same number, and are arranged in a similar manner as the interbrachials of the four other sides. Anal opening subcentral, in the middle of a small projection. Ventral disk depressed. Orals pushed to the anterior side; four of them much smaller, and arranged in a slightly curving row around the posterior one, which rests against the anal protuberance. Covering pieces of the ambulacra exposed at the surface; they consist of two series of very short transverse pieces, alternately arranged, forming highly elevated ridges, which gradually decrease in width as they approach the arms. Interambulacral plates continuous with the interbrachials; they are small, irregular, and form deep depressions upon the surface, which contrast strongly with the elevations along the ambulacra. Column round; axial canal above medium size; the outer edge of the top joint beautifully crenulated.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind., and Racine, Wisc.

*Types* in the American Museum of Natural History, New York.

### **Thysanocrinus occidentalis** Hall.

*Plate XVIII. Figs. 5a, b, c.*

1863. *Glyptaster occidentalis* — Hall; Trans. Alb. Inst., Vol. IV., p. 204 (Abstr. p. 10); also 28th Rep. N. York State Mus. Nat. Hist. (ed. 2.), 1879, p. 133, Plate 13, Figs. 7–11; also 11th Rep. Geol. Surv. Indiana, 1881, p. 262, Plate 12, Figs. 7–11.

1881. *Glyptaster occidentalis* — W. and Sp.; Revision Palæocr., Part II., p. 196.

A somewhat larger species than the preceding. Calyx broadly subturbinate, abruptly spreading from the infrabasals; sides slightly convex; plates thin. The brachials of the calyx have on their outer or dorsal surface a prominent rounded ridge, covered by indistinct longitudinal striæ, and their inner or ventral side has a deep, semi-circular groove. From both sides of the ridge, small radiating lines pass out to the interbrachials, forming triangles of which the intervening spaces are granular or covered with fine striations. Stronger ridges pass from the radials to adjoining basals, where two of them meet, and proceed as a single ridge to the infrabasals. The latter ridges form around the column a sharply defined pentagon, whose salient angles lie in a radial direction.

Infrabasals of moderate size, forming a narrow belt around the column, which is visible in a side view. Basals large, without nodes, rapidly spreading. Radials larger than the costals, second costals narrower than the first. Arms apparently ten, of which in mature specimens the six or seven lower plates are incorporated; arm plates comparatively large, elongate, and slightly wedge-form. Interbrachial plates large; arranged: 1, 2, 3, 3, with a fifth row at the level of the arm bases. Anal interradius considerably wider, having three plates in the second row, and four in the third; — there being no continuous row of anal plates or any sort of elevation. Interdistichals five to seven. Ventral disk unknown. Column round; axial canal of moderate size; pentalobate, the lobes directed radially.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

*Types* in the American Museum Natural History, New York.

*Remarks.* — This species differs from *Thysanocrinus inornatus* in the larger size of the infrabasals, the arrangement of the plates of the anal side, the absence of an anal ridge, and in the general ornamentation of the plates.

*Glyptaster occidentalis* (var.) *inerebescens* is, in our opinion, not sufficiently distinct to be ranked as a variety.

### **Thysanocrinus brachiatus** HALL.

*Plate XVIII. Fig. 7.*

1852. *Glyptaster brachiatus* — HALL; Palæont. N. York, Vol. II., p. 187, Plate 41, Fig. 4.
1881. *Glyptaster brachiatus* — W. and SP.; Revision Palæocr., Part II., p. 196 (Proceed. Acad. Nat. Sci., Phila., p. 370).

Calyx subglobose, having very strong radial ridges which bifurcate at both ends. The lower branches proceed to the basals, and produce a well defined pentagon, subdivided into five nearly equal fields by another row of ridges; the upper branches follow the distichals, and pass into the arms. The general surface without ornamentation.

Infrabasals small, but exposed beyond the column, and visible even in a side view. Basals of moderate size. Radials deeply notched for the reception of the first interbrachial, their lateral faces comparatively short. Costals smaller than the radials. Arms ten, long, slender, somewhat flattened on the back; the three proximal plates take part in the calyx, are curved like the free plates, and are but little larger. The first free brachial is rectangular, but the succeeding ones gradually turn into cuneate, interlock, and finally change to biserial, with the upper and lower faces parallel. Pinnules long and closely packed. Interbrachials: 1, 2, 2. Anal side wider, the plates in three ranges, divided by a vertical row of anal plates; the lower one of the same size as the radials; the others smaller, decreasing in size upwards. Structure of the ventral disk, and form of the anus, unknown. Column pentangular.

*Horizon and Locality.* — Niagara group; Lockport, N. Y.

*Remarks.* — Our description and figure are made from Hall's typical specimen* in the American Museum of Natural History, New York, after clearing away the matrix, which brought to light the pinnules and exposed the calyx plates. That *Glyptaster* is generically identical with *Thysanocrinus*, nobody will doubt after comparing our figure (Plate XVIII. Fig. 7) with that of *Thysanocrinus liliiformis* (Plate XVIII. Fig. 4).

### (?) **Thysanocrinus Halli** (Lyon).

*Plate XIII. Figs. 9a, b.*

1861. *Rhodocrinus Halli* — Lyon; Proceed. Acad. Nat. Sci. Phila., p. 412, Plate 4, Figs. 5*a*, *b*.
1881. (?) *Rhodocrinus Halli* — W. and Sp.; Revision Palæocr., Part II., p. 212.

A large species. Calyx vasiform, a little wider than high, rounded below, the sides convex; the interradial spaces slightly flattened, and the radial plates rather sharply elevated, which gives to the cross-section a subpentangular outline. Surface of the plates smooth, the suture lines distinct but not channeled.

Infrabasals visible beyond the column; the columnar attachment large, circular, its outer margin surrounded by well-defined radiating striæ. Basals large, a little convex; four of them pentangular or nearly so, the upper angles almost meeting the interbrachials, sometimes slightly touching them; the fifth plate pentangular, broadly truncate above. Radials and costals wider than high, gradually decreasing in size upwards. Of distichals only two are preserved, and only in one division of two of the rays. There are only

* Figured by Hall. New York Palæont., Vol. II., Plate 41, Fig. 4.

six interbrachials shown, arranged: 1, 2, 3; but there were probably others above. The anal interradius apparently has two plates in the second row, but the middle one of the next row extends half way down into the second.

*Horizon and Locality.* — Niagara group (?); near Louisville, Ky.

*Remarks.* — The *type* specimen, which was said to be in the Knapp collection, cannot be found. The two specimens here figured, from the Borden Institute of New Providence, Ind., are both somewhat abnormal and quite fragmentary, and leave some doubt as to the generic relations of the species. Not only is the anal plate followed by only two plates, but the first regular interbrachial occasionally touches the basals.

## PTYCHOCRINUS W. and Sr. (Emend.).

1885. W. and Sr.; Revision Palæocr., Part III., p. 99; also Proceed. Acad. Nat. Sci. Phila., p. 321.
Syn. *Glyptocrinus* (in part) — HALL, 1872, 24th Rep. N. York State Cab. Nat. Hist., p. 207; also Miller and Dyer, 1878, Journ. Cincin. Soc. Nat. Hist., Plate 1, Fig. 10.
Syn. *Gaurocrinus* (in part) — S. A. MILLER; 1883, Journ. Cincin. Soc. Nat. Hist., p. 228; and 1889 N. Amer. Geol. and Palæont., p. 276.

Specimens small; in form and mode of ornamentation resembling *Glyptocrinus.* The radial plates marked by a well defined ridge, which passes up and down the median line of the plates, giving to the interradial spaces a somewhat depressed appearance.

Infrabasals five, small, but generally visible beyond the column. Basals five, large; four of them hexagonal, the posterior one heptagonal, truncate above. Radials and costals of nearly equal size. Costals two. Distichals varying in number, curved like arm plates. Arms ten to twelve, rather delicate, and uniserial. Pinnules strong. Interbrachials and interdistichals not numerous, the plates definitely arranged. Posterior side with a longitudinal row of anal plates forming a ridge. The first anal plate in a line with the radials, and always succeeded by a row of three plates, — a second anal and two interbrachials. Structure of ventral disk imperfectly known. Column cylindrical; axial canal large, pentalobate, the lobes directed radially.

*Distribution.* — Restricted to the Trenton and Hudson River groups of America.

*Type* of the genus: *Ptychocrinus splendens* (S. A. Miller).

*Remarks.* — *Ptychocrinus* differs from *Thysanocrinus* in having delicate uniserial arms; from *Reteocrinus* in the definite arrangement of its interradial plates, and in having these resting against the radials; from *Glyptocrinus* in having infrabasals, and an anal plate in contact with the basals.

S. A. Miller, in 1883, arranged a number of species under a proposed genus *Gaurocrinus*, which, like his *Glyptocrinus*, embraces a variety of forms, containing species of *Reteocrinus*, *Glyptocrinus*, and a third form, for which we proposed the name *Ptychocrinus*, with Miller's "*Gaurocrinus*" *splendens* as type. We should have preferred to accept for the latter Miller's name *Gaurocrinus*, if he had not expressly selected as the type of his genus Hall's "*Glyptocrinus*" *Oncalli*, which is a typical *Reteocrinus*.

"*Glyptocrinus*" *priscus* E. Billings, which Walter R. Billings supposed to have infrabasals, and which we placed provisionally under *Ptychocrinus*, has since been referred by us to *Periglyptocrinus*.

### **Ptychocrinus splendens** (S. A. Miller).

*Plate XVIII, Figs. 3a, b.*

1883. *Gaurocrinus splendens* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 230, Plate 11, Fig. 3.
1885. *Ptychocrinus splendens* — W. and Sp.; Revision Palæocr. Part III., p. 101.
1889. *Gaurocrinus splendens* — S. A. Miller; N. Amer. Geol. and Palæont., p. 247.

Calyx elongate, obconical; cross-section pentangular with concave sides. The plates of the rays folded along the median line, so as to form broad, rounded ridges, from which branches proceed to the basals, meeting there smaller ridges from the infrabasals. Surface of plates studded with rather conspicuous, elongate tubercles, of which a transverse one passes over the suture of two adjoining radials without touching the radial ridges. The first interbrachials have seven tubercles, a central one surrounded by six others; the latter occupying the outer margins, resting in part upon adjoining plates. The higher interbrachials have only a central tubercle.

Infrabasals small, only their extreme upper points visible in a side view. Basals large, higher than wide; the posterior one broadly truncated. Radials a little larger than the basals, about as long as wide. First costals somewhat longer than wide, and hexagonal; the upper angles of the axillaries not truncated, the interdistichals not touching them. Distichals twelve to fourteen, of which the three to four lower ones take part in the calyx, the succeeding ones being free arm plates; the upper one gives off two arms, which remain simple. Arms delicate, gradually tapering to a slender point; composed of a single series of rather long, wedgeform joints. Pinnules stout, widely separated. The first pinnule, which is fixed, more erect, and stronger than the others, is given off from the outer side of the second distichal, the second from the inner side of the fourth plate; all succeeding plates except the axillaries being pinnule-bearing. Interbrachial spaces deeply depressed; the first plate large, followed by two smaller ones, and these by three in the third row, and others above. Anal side wider, somewhat angular along the median line; the first anal plate resting upon the truncate basal. Interaxillaries three, in two ranges; each one marked by a small, central tubercle. Construction of disk and form of anus unknown. Column round, slightly tapering; the nodal joints at their outer edges faintly crenulated; axial canal large, pentalobate.

*Horizon and Locality.* — Trenton group; Cape Girardeau, Mo., and Alexander Co., Ill.

*Types* in the collection of S. A. Miller, Cincinnati.

### **Ptychocrinus parvus** (Hall).

*Plate XVIII, Figs. 1a, b* and 2.

1872. *Glyptocrinus parvus* — Hall; Descr. New. Crin., *etc.*, Plate 1, Fig. 17 (without description); also 24th Rep. N. Y. State Cab. Nat. Hist., p. 207, Plate V., Fig. 17.

1873. *Glyptocrinus parvus* — Meek; Paleont., Ohio, Vol. I., p. 36, Plate 2, Figs. 4*a*, *b*.

1879. *Glyptocrinus angularis* — Miller and Dyer; Journ. Cincin. Soc. Nat. Hist., Plate 1, Fig. 10.

1881. { *Glyptocrinus parvus* / *Glyptocrinus angularis* / *Reteocrinus gracilis* } — W. and Sp.; Revision Palæocr., Part II., pp. 188, 189; and Amer. Journ. Sci., 1883, Vol. XXV., pp. 255–268.

1881. *Reteocrinus gracilis* — Wetherby; Cincin. Journ. Nat. Sci., Vol. IV., Plate 2, Fig. 2.

1883. { *Glyptocrinus parvus* / *Gaurocrinus angularis* } — S. A. Miller, Journ. Cincin. Soc. Nat. Hist., Vol. VI., pp. 224 and 229; and 1889, North Amer. Geol. and Paleont., pp. 247 and 248.

1885. { *Ptychocrinus parvus* / *Ptychocrinus angularis* } — W. and Sp.; Revision Palæocr, Part III., p. 100.

Of small size. Calyx obconical, with slightly convex sides; the radial plates marked with prominent rounded ridges, which extend to nearly the full width of the plates; interbrachial spaces flat, plates very slightly convex and without ornamentation.

Infrabasals minute, only the outer angles of the plates visible beyond the column. Basals large, higher than wide; their surfaces strongly convex. Interbasal sutures deeply depressed, and the depression continued to the radials, of which the lower ends bend inward. Radials somewhat larger than the first costals. The second costals of similar form to the radials, only reversed, being angular above instead of below. Distichals 2 × 10, about as wide as long, the upper one axillary. Arms four to the ray, free from the first or second palmar; composed of wedgeshaped joints, which are as long as wide, and rounded on the back. Pinnules stout, well separated. Interbrachial spaces depressed, flat; the first plate of the regular sides as large as the costals; followed by two plates in the second row, and a number of others, which, though well defined, are more or less irregular in their arrangement. Anal side wider, divided by a longitudinal row of hexagonal plates; the plates at each side of this row about as numerous as the whole series of plates of the four regular sides. Interaxillaries five or more. Construction of the ventral disk unknown. Column round; axial canal of medium size.

*Horizon and Locality.* — Hudson River group; Cincinnati, O.

*Remarks.* — *Glyptocrinus* (*Gaurocrinus*) *angularis* Miller, and *Reteocrinus gracilis* Wetherby, are undoubtedly synonyms of Hall's "*Glyptocrinus*" *parvus*. Mr. Miller was good enough to send us two specimens, which he had himself identified as "*Gaurocrinus*" *angularis*, and Mr. Vaupel kindly loaned us the type of *Reteocrinus gracilis*. Both specimens are figured on Plate XVIII., and a comparison of them with Hall's type of "*Glyptocrinus*" *parvus* will prove that they all represent one species.

## HYPTIOCRINUS, W. and Sp.

(ὕπτιος, bending back; κρίνον, a lily).

1892. W. and Sp.; Am. Geologist, Vol. X. (September), p. 138.
Syn. *Cyphocrinus* S. A. Miller (October 26, 1892); Adv. Sheets, 18th Rep. Geol. Surv. Indiana, p. 56.

Name referring to the character of the arms, which hang downward. Calyx depressed, wheel-shaped. Infrabasals five, small. Basals five, four of them equal, angular at the upper end; the posterior one truncated by the anal plate. Radials comparatively small, all heptagonal. Costals two. Fixed brachials rather large, except the first costals, which are quite short, and quadrangular. Distichals one, the distal face broadly truncated; followed by several sharply cuneate pieces, which interlock, and of which the two or three proximal ones (in the type) take part in the calyx. Arms stout, probably biserial, and pendent, to judge from the arm openings, which are directed obliquely downward. First interbrachials of the regular sides very large, succeeded by several rows of smaller pieces. Anal plate touching the basals and rising above the radials; supporting three much smaller plates and others above. Ventral disk depressed; the posterior oral and the radial dome plates spinous; the anus excentric and at the top of a large protuberance.

*Distribution.* — So far as known, restricted to the Niagara group of Indiana.

*Remarks.* — The genus has its closest relations with *Thysanocrinus*, from which it differs in the depressed form of the calyx, the pendent arms, and in the spine-bearing disk.

### **Hyptiocrinus typus** W. and Sp. (nov. spec.).

*Plate XIX, Figs. 6a* to *c.*

1892. W. and Sp.; Am. Geologist, Vol. X. (September), p. 138.
Syn. *Cyphocrinus Gorbyi* S. A. Miller (October 26, 1892). Adv. Sheets 18th Rep. Geol. Surv. Indiana, p. 51, Plate 7, Figs. 14, 15, 16.

Specimens of medium size. Calyx wheel-shaped, nearly once and a half as wide as high. Dorsal cup broadly obconical to the top of the costals, then flanging outward and somewhat downward. Arm regions not lobed, but the upper margins of the interbrachial and interdistichal spaces formed into sharp edges by means of corresponding depressions in the dorsal cup and tegmen. Costals and distichals marked by rounded, longitudinal ridges, following the median line of the plates. Ventral disk a little higher than the dorsal cup, its lateral margins slightly bulging, the lower edge somewhat projecting over the upper margin of the dorsal cup. Plates flat, their surface in well preserved specimens densely covered by fine granules.

Infrabasals small, hidden by the column; forming a flat pentagonal disk. Basals rather large, about as wide as long; curving abruptly upwards; the posterior one slightly truncated at the upper end; the interbasal suture lines distinctly grooved. Radials twice as wide as long, their proximal ends distinctly angular. First costals much shorter and narrower than the radials; quadrangular. Second costals longer and a little wider than the first; their lateral faces short; the sloping upper faces making a right angle. First distichals as large as the axillary costals, followed by two or three cuneate plates in the calyx, which slightly interlock. Structure of the free arms not observed, but they were apparently biserial and quite heavy and pendent. First interbrachials of the regular sides the largest plates of the calyx, rising to the height of the first distichals, and being succeeded by two rows of two plates each. The anal plate a little higher than the radials, supporting three, two, and two, smaller plates. Interdistichals one, small. Posterior oral nearly central, large, and extended into a heavy, short spine; the other four orals proportionally small and almost flat. Radial dome plates represented by plates of a first and second order, those of the latter by two or three plates to each division, alternately arranged; all large and spine-bearing. The spines near the outer margins of the disk project obliquely outward, and are visible from a dorsal view of the calyx. Interambulacral plates numerous, of the size of the smaller orals, and irregularly arranged. Anus excentric, at the top of a large ovoid protuberance, rising conspicuously above the general plane of the disk.

*Horizon and Locality.* — Niagara group; St. Paul, Shelby Co., Ind.

*Type* in the collection of Wachsmuth and Springer.

### IDIOCRINUS W. and Sp. (nov. gen.).

(ἴδιος, peculiar; κρίνον, a lily).

1892. W. and Sp.; Am. Geologist, Vol. X. (September), p. 135.
Syn. *Gazacrinus* S. A. Miller (October 26, 1892); Adv. Sheets, 18th Rep. Geol. Surv. Indiana, p. 49.

Infrabasals apparently five, extremely small, placed at the bottom of a more or less deep concavity, and completely hidden by the column. Basals five, very large; the posterior one truncated by the anal plate. Radials quite large; three of them heptagonal, the two adjoining the anal side hexagonal. Costals two, very short; the first quadrangular; the second pentangular, the upper angle rather obtuse. Distichals two in the calyx; short. Interradial areas at all sides composed of a single large plate, which rises to the top of the dorsal cup; that of the anal side resting upon the basals, the four others upon the sloping upper faces of the radials. Ventral disk quite variable in form; covered by a large, probably anchylosed oral pyramid. The ambulacra tegminal; the interambulacral spaces formed of single plates, of which the posterior one is perforated by the anus, which is excentric. Arms and column unknown.

*Type.* — *Idiocrinus elongatus.*

*Distribution.* — So far as known, restricted to the Niagara group of America.

*Remarks.* — This genus differs from all other dicyclic Camerata in having a single plate in the anal area, in its central, undivided oral pyramid, and in having but one interambulacral plate to each side of the disk.

**Idiocrinus elongatus** W. and Sp.

*Plate XVIII. Figs. 8a* to *c.*

1892. W. and Sp., Am. Geologist, Vol. X. (September), p. 136.
Syn. *Gazacrinus inornatus* S. A. Miller; Adv. Sheets 18th Rep. Geol. Surv. Indiana, p. 49, Plate 5, Figs. 9, 10, 15, 16, 17 (published October 26), 1892.

A small species. Calyx obconical; the ventral disk almost on a level with the upper margins of the dorsal cup; the cup deeply excavated at the bottom, the basals forming a large funnel-shaped pit. Plates without ornamentation and flat, except the radials, which are a little convex, and rise slightly above the plane of the cup. Suture lines not grooved.

Infrabasals minute, constituting the bottom of the basal concavity. Basals extremely large and elongate, the lower end curving abruptly inward, and forming a sharp edge around the bottom of the calyx; the exposed part of the plates rising to more than one third the length of the dorsal cup. Radials once and a half as wide as long, distinctly angular at their lower faces; the two posterior plates hexagonal, being distinctly truncated by the anal plate. Costals together less than half the size of the radials; the first linear; the second a very little longer, and its upper angles quite obtuse. Distichals two, somewhat higher and wider than the costals; the upper semifree. Interbrachials one, those of the four regular sides resting upon the deeply sloping sides of the radials, the anal one upon the narrowly truncated basal; all extending to the upper end of the calyx, and all longer than wide. Arms apparently ten, their dorsal faces flat.

Ventral disk but slightly elevated, consisting of five large, oblong, triangular plates, one to each area, which do not meet in the centre, but leave a moderately large, pentalobate open space at the summit. The sides at the lower ends of the plates to two thirds their length are not in contact, but leave elongate spaces, which were apparently occupied by the ambulacra; the lateral edges are slightly serrated, and bend outward for the reception of the covering pieces. Near the summit, the plates meet in a similar manner as the deltoids of the Blastoid genus *Pentremites*, by means of lateral processes, and these are converted into grooves which communicate with the vacant space in the centre. The structure is such as to indicate that the ambulacra followed these grooves before entering the peristome, and that the centre was covered by an oral pyramid, as in the allied *Idiocrinus ventricosus*, in which the pyramid was found in position. The posterior interambulacral plate is somewhat wider, and perforated by the anus to such an extent as to leave only a narrow skeleton at the lateral margins.

*Gazacrinus* Miller is identical with *Idiocrinus*, the latter name having priority. Miller described the genus as monocyclic instead of dicyclic, and he speaks of a "vault sustained by a specialized frame work with ambulacral canals connecting the arms with the central orifice." This is misleading, for the plates exposed at the oral surface are true plates of the disk, and the open spaces which appear in the specimens were closed by orals and ambulacral plates. There was no central orifice, the peristome being covered as in all other Camerata.

*Horizon and Locality.* — Upper part of Niagara group; St. Paul, Shelby Co., Ind.

*Type* in the collection of Wachsmuth and Springer.

*Remarks.* — Mr. Miller, in describing the arm plates of this species, states they are long, and their edges "are transversely serrated on the inside, half the depth of the plates." We observed this structure in our specimen, and were at first inclined to regard the edges as formed of small side pieces, and so described them in the "American Geologist." Since then on further cleaning the specimen, we have become convinced that the parts in question are mere extensions of the arm plates, which are short, and that the line of union is slightly gaping to facilitate motion.

Another point in Miller's description should be noticed. He says: "There are three longitudinal furrows on the inside of each radial series, shown at the top of the secondary radials; this gives fifteen furrows at the top of the secondary radials, one in the middle of each plate, and the other at the suture;" and he alludes to this as a peculiarity entirely new to him. He evidently misunderstood the structure, for our specimen clearly shows but one furrow to each brachial, of which those from the distichals unite upon the axillary costals at the extreme edge of the disk. The supposed marginal furrows do not enter the disk, and are mere depressions at the lateral margins of the distichals, formed by the highly projecting serrated edges of the ambulacral furrows at each side.

**Idiocrinus ventricosus** W. and Sp. (nov. spec.).

*Plate XVIII. Figs. 9a, b.*

A very small species. Calyx as wide as high; height of dorsal cup about equal to that of the tegmen; the former bowl-shaped, the cup obtusely pyramidal. Plates smooth; the radials and costals somewhat longitudinally convex, causing a small depression of the interbrachial spaces. Suture lines slightly grooved.

Infrabasals extremely small, and completely covered by the column; placed at the bottom of a small circular cavity, formed by the lower ends of the basals. Basals of moderate size, their lower ends incurving and forming the sides of the concavity, their upper angles slightly bending upwards. Radials once and a half as large as the two costals together, and twice as wide as long; three of them heptagonal, the two posterior ones hexagonal. First costals quadrangular, much narrower than the radials, and three times as wide as long; the second of nearly the same width as the first, but longer. Distichals narrower and shorter than the second costals. Interbrachials large, subelliptical; that of the anal side a little wider, and slightly truncating the posterior basal. Oral pyramid convex, a very little tumid, extremely large for the size of the species, perfectly closed at the summit, and the inter-oral sutures obsolete. The outer surface of the pyramid is covered with well defined radiating ridges, which proceed from the middle of the plate to the outer margins, increasing in height and width as they pass outward. Ten of these ridges are prominent, and project outward around the circumference, thus giving to the plate the aspect of a ten-rayed star. The inner floor is excavated centrally, and there are five deep grooves passing out in a radial direction. The interambulacral plates long, slender and cuneate, attached with their sharp upper ends to the inner margins of the orals. They project outward so as to form at their sides open spaces for the reception of the ambulacra. Other parts unknown.

*Horizon and Locality.* — Upper part of Niagara group; near St. Paul, Ind.

*Type* in the collection of Wachsmuth and Springer.

*Remarks.* — The oral pyramid of this species, which is found occasionally detached from the body, was regarded by Miller, Benedict, and ourselves, as probably representing the ventral structure of a *Pisocrinus.* This appeared quite plausible, as it was expected from analogy that in *Pisocrinus,* as in the allied *Symbathocrinus*, *Allagecrinus* and *Haplocrinus*, the ventral disk consisted of orals only, and the plate fitted approximately upon the cup of one of the species, which occurs in the same bed. A well preserved oral pyramid of this genus is figured on Plate III. Fig. 15, which may belong to this species.

### (?) **Idiocrinus immaturus** (Hall).

*Plate XVIII, Figs. 10a, b, c.*

1851. *Thysanocrinus immaturus* — Hall; Palæont. N. York, Vol. II., p. 191, Plate 42, Figs. 4c–f.

This small species, so far as known, in its general habitus so closely resembles *Idiocrinus* that we are inclined to regard it as belonging to this genus. It is more depressed than *I. elongatus*, the sides of the cup are more convex, the base more concave, and the costals proportionally higher. Neither arms nor ventral disk are known.

*Horizon and Locality.* — Niagara group; Lockport, N. Y.

### (?) **Idiocrinus tennesseensis** (Worthen).

*Plate XVIII, Fig. 11.*

1890. *Centrocrinus tennesseensis* — Worthen; Geol. Rep. Illinois, Vol. VIII., p. 95, Plate 14, Fig. 1.

Dorsal cup apparently obconical. Plates almost flat, and without ornamentation; suture lines indistinctly grooved.

Infrabasals three, forming a slightly projecting rim around the bottom of the calyx. Basals rather large, fully as high as wide, three of them pentangular, the others being covered by matrix. Radials one fourth wider than long, the lower faces distinctly angular. Costals two, narrower than the radials; the first quadrangular and extremely short, more than three times as wide as long; the second a little longer than the first, and obtusely angular above. Distichals two in the calyx; the proximal one as long as, or longer than, the axillary costal; the second a little wider than the free arm plates, but not higher. Arms two from the calyx, moderately stout; composed of rather long, quadrangular joints, branching (at least in one of the arms) from the fourth free plate. Interbrachials, as seen at two sides, subelliptical, extending to the full height of the first distichals, slightly grooved longitudinally at the median line. Stem round, the nodal joints high, the outer faces convex and somewhat projecting. All other parts of the species unknown.

*Horizon and Locality.* — Niagara group; near Clifton, Wayne Co., Tenn.

*Type* in the Illinois State collection, Springfield.

*Remarks.* — We refer the above species to this genus with considerable doubt, although it has close affinities with it in the structure of the dorsal cup; but it differs from the typical form in having three rather large, projecting infrabasals — that having apparently five — and the plates are completely covered by the stem. Whether it has the same sort of ventral disk cannot be ascertained from the specimen, nor do we know anything about the structure of the anal side. Worthen referred the species to the monocyclic genus *Centrocrinus*, and apparently took the infrabasals for a projecting rim of the basals.

## LAMPTEROCRINUS Roemer.

1860. F. Roemer; Silur. Fauna. West. Tenn., p. 37.
1863. Hall; Trans. Albany Institute, Vol. IV., p. 202.
1866. Shum.; Trans. Acad. Sci. St. Louis (Cat. Palæoz. Foss., p. 378).
1868. Hall; 20th Rep. N. York State Cab. Nat. Hist., p. 328.
1879. Zittel; Handb. der Palæontologie, Vol. I., p. 375.
1881. W. and Sp.; Revision Palæocr., Part II., p. 199 (Proceed. Acad. Nat. Sci., Phila. 1881, p. 373).
1882. De Loriol; Paléont. Française, Tome XI. (Crinoïdes), p. 59.
1885. W. and Sp.; Revision Palæocr., Part III., p. 101 (Proceed. Acad. Nat. Sci. Phila., p. 323).
1889. S. A. Miller; N. Amer. Geol. and Palæont., p. 257.
Syn. *Balanocrinus* — Troost, 1850 (not Agassiz, 1846), Cat. Foss. Tenn., p. 60.

Calyx unsymmetrical, elongate-obpyramidal, the rays formed into tubular appendages bearing the arms. Ventral disk greatly inflated posteriorly, and extended into a large tube, pushing the centre of radiation to the anterior side of the calyx.

Infrabasals anchylosed, forming a large spreading cup. Basals five, very large, four of them equal, angular above; the posterior one considerably higher, and truncated at the upper face. Radials very large. Costals two, the first hexagonal, the second supporting at one side a lateral arm, at the other the distichals. The higher orders of radials, from the distichals up, are curved like arm plates, and with the covering pieces form a rigid tube, from which small arms are given off alternately at intervals. In the typical species the distichals consist of three short pieces, the upper one axillary, supporting at one side the second arm, at the other the palmars, of which only the first plate has been observed.

Interbrachials large, passing uninterruptedly from the dorsal cup into the tegmen; there is one plate in the first row, followed by two in the second. At the anal side, which is somewhat wider, the first anal plate rests upon the basals, and supports three small plates in the next range, which are succeeded by three plates, and others above. Ventral disk asymmetrical, strongly bulging at the posterior side, and supporting a large central tube. Orals large, excentric.

Column pentangular; axial canal small.

*Distribution.* — Niagara group of America.

*Remarks.* — We only recognize Roemer's typical species. Hall's *Lampterocrinus inflatus* (*Balanocrinus sculptus* Troost MS.) has never been described, and the figure * was made from a natural cast, of which the anal side is not seen. *Lampterocrinus parvus* † was also described from very imperfect material.

*Lampterocrinus*, by its asymmetry, and the position of its anal tube, is very closely allied to *Siphonocrinus;* but it is readily distinguished by its arm structure.

### **Lampterocrinus tennesseensis** Roemer.

*Plate XIII. Figs. 10a, b, c, d.*

1860. Roemer; Silur. Fauna West. Tenn., p. 37, Plate 4, Figs. 1*a*, *b*.
1881. W. and Sp.; Revision Palæocr., Part II., p. 201.
Syn. *Balanocrinus sculptus* Troost (Catalogue name).

Calyx elongate, more than once and a half as high as wide, decidedly asymmetrical. Dorsal cup higher than wide, spreading abruptly to the middle of the radials, where it attains almost its full width; cross-section pentangular. Plates convex, their surface ornamented with conspicuous radiating ridges, passing from the centre of one plate to the centre of another — there being one ridge for each side of the plates — dividing the surface into well marked, deeply impressed areas. The ridges are angular, knife-like, their edges more or less serrated; those from the infrabasals to the basals, and thence to the radials, and between radials and costals, and to the first interbrachials, are more prominent than those of the higher interbrachials, but the centre of the latter is raised into a small, sharp node.

Infrabasals five, completely anchylosed, forming a small cup; the suture lines obliterated by extraordinary secretion of calcareous matter, and raised into sharp ridges, passing out from the angles of the column to the lower

* 28th Rep. N. York State Museum Nat. Hist., Plate 10, Fig. 6.
† 11th Rep. of Geol. and Nat. Hist. State of Indiana, Plate 15, Fig. 6.

angles of the basals; the truncated part sharply pentangular, and completely occupied by the column. Basals very large, as long as wide, and angular above; the posterior one considerably longer, and its upper face truncated. Radials fully twice as large as the first costals, and somewhat larger than the basals. Second costals smaller than the first, and facing outward, the sides slightly incurving; their sloping upper faces unequal, the shorter side bearing a lateral arm, and the longer one a row of distichals. The higher orders of brachials, which are roofed over by rigid covering pieces, are formed into tubular appendages, from which at intervals armlets are given off alternately. The second arm starts from the third distichal, and it is probable that each succeeding arm is given off from the third plate of successive brachials. The appendages are preserved in the specimens only to the first palmar. Interbrachials: 1, 2, 3; the first as large as the first distichal; those of the second and third row much smaller. Anal side a little wider and bulging from below the base of the free rays upwards; the anal plate, which is even larger than the first radials, is followed by three not very large plates, and these by successive rows of three plates each, which pass into the anal tube; the plates of the middle row are marked by a conspicuous angular ridge, which extends from the angles of the column to the base of the anal tube, and runs parallel to the ridges upon adjacent radials and costals. Ventral disk elevated; composed of few rather large, convex or slightly nodose plates, which are continuous with the interbrachials. The anal tube is constructed of similar somewhat smaller plates; it is central, but bends abruptly to the anterior side of the calyx; its length not known. Orals not larger than the other plates of the tegmen; they are excentric, being pushed completely to the anterior side. Column near the calyx sharply pentangular, with a small node at the angles of each joint.

*Horizon and Locality.* — Upper part of the Niagara group; Decatur and Wayne Cos., Tenn.

*Types* in the Mineralogical Museum at Breslau, Germany.

## SIPHONOCRINUS S. A. Miller (redefined, W. and Sp.).

1888. Miller; Amer. Geologist, Vol. I., p. 263; and 1889, Amer. Geol. and Palæont., p. 281.
Syn. *Eucalyptocrinus* (?) — McChesney, 1859; Descr. New Species, p. 95.
Syn. *Glyptocrinus* — McChesney; Chicago Acad. Sci., 1868, Vol. I., p. 23; and Hall, 1861; Rep. of Progr. Geol. Surv. Wisc. for 1860, pp. 21 and 22; and Hall, 1867; 20th Rep. N. York State Cab. Nat. Hist., p. 328.

Known only from natural casts and impressions from the natural moulds in the rock. Calyx large, oblong, its form extremely asymmetrical. Dorsal cup deeply depressed interradially, the rays projecting so as to give to the calyx a strongly lobed outline. Ventral disk generally as high as the dorsal cup; its posterior side inflated from below the brachial zone to the summit, forming a conspicuous helmet-shaped protuberance, which at the arm regions not only occupies the whole width of the posterior interradius, but encroaches largely upon the left posterior ray, not involving the ray to the right, from which it is separated by a deep groove. This protuberance, as seen from the casts, grows narrower at the summit, and the upper part either bends directly upwards, in the form of a central tube, or is continued across the summit to the anterior side, where it opens out to the exterior at — or even beneath — the arm bases.

Infrabasals five, elongate, variable in form; four of them, as a rule, angular above; the posterior one broadly truncate, supporting the first anal plate. Radials decidedly angular below. Costals two; the first generally hexagonal. Distichals varying from two to four in different rays, there being generally two in the anterior rays against three or four in the posterior ones. The interbrachials, which are numerous and of rather large size, pass uninterruptedly from the dorsal to the ventral side of the calyx, and are in contact with the interambulacrals. The first plate of the regular sides rests deeply between the sloping upper faces of two radials, its lower angle exceptionally touching the basals; there being two plates in the second row, and generally three in the third. Anal side wider and larger throughout; the first anal plate placed upon the truncated basal, supporting three plates in the first row, and three or more in all succeeding rows. The ventral surface of the casts is marked by well defined ridges, converging from the arm bases to a pentangular, somewhat elevated space behind the anus, the centre of which is represented by a small cone. These converging ridges are open grooves or galleries at the inner floor of the disk for the reception of subtegminal ambulacra, and the pentangular space in front of the anus represents the peristome, of which the mouth occupies the median part. Anal opening placed at the distal end of a tube, which is either erect and passes outward at the summit of the disk, giving to the mouth an excentric position, or is continued beneath the plates of the disk to the anterior side of the calyx, where it opens out interradially or interdistichally at — or below — the arm regions. Ventral disk covered with comparatively large plates, forming a sort of vault, in which neither orals nor covering pieces can be distinguished.

*Distribution.* — Only known from the Niagara group of America.

*Type* of the genus. — *Siphonocrinus armosus* (McChesney).

*Remarks.* — This genus, by its asymmetrical form, is closely allied to *Lampterocrinus*, from which it differs as stated under that genus.

S. A. Miller, in proposing the genus, described it as having three infrabasals. We have examined more than eighty specimens, from the collections of Mr. W. C. Egan of Chicago, and Mr. F. A. Greene of Milwaukee, and satisfied ourselves that they all have five plates in the proximal ring.

In studying the figures, it must not be overlooked that most of them represent natural casts of the *internal* surface of the test, the plates themselves having been dissolved by chemical action, and that on these all elevations represent depressions of the inner floor. Only in the figures made from casts in the natural *moulds* does the surface represent the true external surface of the plates.

### **Siphonocrinus armosus** (McChesney).

*Plate XIX. Figs. 3a, b, c.*

1859. *Eucalyptocrinus armosus* — McChesney; Descr. New Palæoz. Foss., p. 95.
1867. (?) *Glyptocrinus armosus* — McChesney; Trans. Acad. Sci. Chicago, p. 23, Vol. I., Plate 7, Figs. 6a, b.
1881 (?) *Glyptaster armosus* — W. and Sp.; Revision Palæocr., Part II., p. 196.
1882. *Glyptocrinus armosus* — Whitfield; Geol. Surv. Wis., Vol. IV., p. 284, Plate 16, Fig. 11.
1888. *Siphonocrinus armosus* — S. A. Miller; Amer. Geologist, Vol. I., p. 264.
Syn. *Glyptocrinus siphonatus* — Hall; Rep. of Progr., Geol. Surv. Wis., p. 22; and 20th Rep. N. York State Cab. Nat. Hist., Plate 10, Fig. 11.

A large species, only known from internal casts. Calyx subovoid. Dorsal cup generally higher than the ventral disk, its sides decidedly convex, subglobose; section across the arm bases slightly lobed.

Infrabasals small, forming a shallow cup. Basals as large as the first costals, the upper angles unusually sharp, exceptionally touching the interbrachials. Radials larger than the costals; the first costals larger than the second, and hexagonal. Distichals and palmars in series of two each. Arms four to the ray, their structure unknown. The plates of the regular interbrachial spaces generally consist of four rows, arranged: 1, 2, 2, 3; the first plate as large as the first costal. Anal interradius considerably wider, greatly bulging from below the arm bases; the first anal higher than the radials, succeeded by three plates in the second and third rows, and numerous irregular, rather large plates at the disk. The latter plates together form a trumpet-shaped inflation, apparently representing a subtegminal anal tube, which crosses the mouth, overlies the upper part of the anterior ambulacra, and is continued subtegminally all the way to the anterior side of the calyx, even beyond the arm regions, where it bends outward. The ambulacra, as seen from the converging ridges upon the casts, vary considerably in length in some of the rays, the posterior ones being much longer, especially those to the left, which are quite conspicuously displaced. The excentric position of the mouth, and the irregular arrangement of the ambulacra of this species remind us of the Comatulid genus *Actinometra.*

*Horizon and Locality.* — Upper part of Niagara group; Racine, Greenfield and Waukesha, Wisc., and Chicago, Ills.

### **Siphonocrinus nobilis** (Hall).

*Plate XIX. Figs. 1a, b, and 2a, b, c.*

1861. *Glyptocrinus nobilis* — Hall; Rep. Progr. Geol. Survey Wisc., p. 21; also 1867, 20th Rep. N. York State Cab. Nat. Hist., Plate 10, Figs. 9, 10.
1881. (?) *Glyptocrinus nobilis* — W. and Sp.; Revision Palæocr., Part II., p. 189.
1882. *Glyptocrinus nobilis* — Whitfield; Geol. Wisconsin, Vol. IV., p. 282, Plate 16, Figs. 9, 10.
1888. *Siphonocrinus nobilis* — S. A. Miller; Amer. Geologist, Vol. I., No. 5, Fig. 265.

Calyx as large as in the preceding species, and of similar form; but the ventral disk proportionally higher, and the anal tube directed upwards, not being conducted subtegminally to the anterior side of the calyx. The ornamentation — as observed in gutta percha casts taken from natural moulds in the rock — is characterized by sharp radiating ridges, passing from the centre of each plate to adjoining ones, and presenting upon the surface of each a well defined stellate figure with a slight elevation in the centre. A similar style of ornamentation, but less distinct, occurs upon the plates of the disk and anal tube.

Infrabasals and basals as in *S. armosus;* the latter with sharp upper angles reaching far up between the radials, and sometimes meeting the first interbrachials. Costals smaller than the radials. Distichals three, large; succeeded by several palmars, which are but little larger than good sized arm plates. There are four arm openings to the ray, arranged in pairs, with a shallow depression between each pair, and a somewhat wider and deeper one between the pairs of different rays, the latter extending quite a distance into the ventral surface, and forming deep grooves along the margin. Arm structure unknown. Interbrachials: 1, 2, 2, 2, 3; succeeded in the disk by comparatively large, less regularly arranged plates, which completely cover mouth and ambulacra, apparently without the assistance of orals. Anal side greatly protruding, forming an immense projection, which begins in the dorsal cup, and extends to over one third of the whole surface of the disk, giving to the specimen an exceedingly irregular form. The projection resembles an inflated sac, which toward the upper end grows decidedly smaller, and on approaching the summit turns abruptly upwards in form of a good sized tube. The first anal plate rests upon the broadly truncated posterior basal, and is followed by three plates in the second, and three or more in the succeeding rows. Interdistichals 1, 2, 2; the lower plate resting upon the upper sloping faces of the second distichals. The inflation upon the disk, as appears from the impressions, was covered by a large number of plates without definite arrangement. There were a few large plates, surrounded by smaller ones, all slightly convex and ornamented in a similar manner. Mouth excentric, marked in the casts by a stellate protuberance, from which the ambulacra pass out to the arm openings. Column unknown.

*Horizon and Locality.* — Same as last.

**Siphonocrinus pentagonus** W. and Sp. (nov. spec.).

*Plate XIX. Figs. 4a, b.*

A large species, of the type of *S. nobilis*. Calyx decidedly asymmetrical, about as high as wide, strongly lobed at the arm regions; the depressions deep and wide. Posterior side of the calyx enormously inflated from the top of the anal plate to the summit of the disk, the bulging involving the left posterior ray, which projects more conspicuously than the others. Dorsal cup obconical, the sides evenly spreading to the top of the costals, thence more rapidly to the arms. The upper angles of the basals and lower angles of the interbrachials more obtuse than in the preceding species, and never in contact. Radials, costals, and interbrachials of nearly uniform size; the first costal somewhat larger than the second. The first distichal as large as the upper costal, the two following considerably smaller, the succeeding ones free arm plates. Arm structure unknown. Interbrachials 1, 2, 3, followed by interambulacrals. The anal plate is succeeded by three and four plates, the latter supporting the plates of the anal protuberance, which on approaching the top of the disk contracts rapidly, and turning abruptly upward, forms a tube at the summit. Ventral disk one fourth shorter than the dorsal cup; the mouth quite excentric, and the posterior ambulacra considerably longer.

*Horizon and Locality.* — Same as last.

*Type* in the collection of W. and Sp.

*Remarks.* — This species is readily distinguished from the preceding species by having but two arms to the ray from the calyx, which, however, may branch in their free state.

# RHODOCRINIDÆ Roemer (1855).

Dicyclic. Lower brachials and interbrachials forming an important part of the dorsal cup. Radials separated all around by an interradial plate which is followed by well-defined, regularly arranged interbrachials.

*Analysis of the Genera.*

**Infrabasals 5. Basals 5.**

A. Anal interradius generally with additional plates.
  1. *Arms uniserial.*
    a. *Arms not branching.*
      Basals exposed in a side view . . . . . . . . . . Rhaphanocrinus.
  2. *Arms biserial.*
    a. *Arms branching.*
      Calyx obovate: anus without a tube; interbrachials numerous, two in second row; interdistichals generally present . . . . . . . . . . . . . . . Archæocrinus.
      Calyx depressed globular, anus at end of a tube, first interradials frequently separated from basals by supplementary pieces. No interdistichals. Arms probably given off from brachial prolongations of the calyx . . . . . . . . . . . . . . . . Diabolocrinus.
      Calyx globose, flattened or concave below; two or three interbrachials in second and succeeding rows; no interdistichals.
        Ventral disk narrower than dorsal cup . . . Rhodocrinus.
        Ventral disk equal to, or exceeding dorsal cup; tubular appendages suspended from margin of disk . . . . . . . . . . . . Gilbertsocrinus.
    b. *Arms not branching.*
      Calyx globose, arms long and heavy; interdistichals numerous . . . . . . . . . . . . . . . . Thylacocrinus.

B. Anal interradius without additional plates.
  1. *Arms biserial.*
    a. *Arms not branching,* dorsal cup broadly truncate at the bottom, radials sometimes not all separated; arm facets directed upward . . . . . . . . . . . . . . . . Lyriocrinus.
    b. *Arms branching.*
      One costal; interdistichals few . . . . . . . . . . Anthemocrinus.
      Two costals; rays produced into long trunks giving off armlets from opposite sides . . . . . . . . . Ripidocrinus.

C. Anal interradius unknown.
  Arms uniserial, branching frequently; infrabasals very small . Diamenocrinus.

*Geological and Geographical Distribution.*

**Number of known species.**

(Open figures indicate American, those marked ( ), European.)

| Formation. | | | Rhodocrinidæ. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General. | American. | Approximate European Equivalents. | Rhaphanocrinus. | Archæocrinus. | Diabolocrinus. | Rhodocrinus. | Gilbertsocrinus. | Thylacocrinus. | Lyriocrinus. | Anthemocrinus. | Ripidocrinus. | Diamenocrinus. |
| Subcarboniferous. | Keokuk. | Mountain Limestone. | | | | 3 | 2 | | | | | |
| | Upper Burlington. | | | | | 3 (5) | 3 (4) | | | | | |
| | Lower Burlington. | | | | | 5 | 4 | | | | | |
| | Kinderhook. | | | | | 3 | | | | | | |
| Devonian. | Hamilton. | Up. Devon. | | | | 1 | 1 | 1 (2) | | | | |
| | Upper Helderberg. | Eifel bed. | | | | (2) | | | | | (1) | (1) |
| Silurian. | Niagara. | Wenlock. Gotland. | | | | | | | 2 (1) | (2) | | |
| | Hudson River. | | 1 | | | | | | | | | |
| | Trenton. | | 1 | 4 | 2 | | | | | | | |
| Total species 54 { 36 (18) | | | 2 | 4 | 2 | 15 (7) | 10 (4) | 1 (2) | 2 (1) | (2) | (1) | (1) |

*Remarks.* — When Roemer established the Rhodocrinidæ, he was acquainted only with the genus *Rhodocrinus*, in which he included also the species which were afterwards referred to *Ripidocrinus* and *Gilbertsocrinus.* He omitted *Acanthocrinus*, which he had himself proposed in 1850, probably having discovered its identity with *Rhodocrinus.*

The earlier French writers, d'Orbigny, de Koninck, Pictet, and Dujardin and Hupé, placed *Rhodocrinus* with the Cyathocrinidæ.

The Rhodocrinidæ of Zittel and de Loriol embrace *Rhodocrinus*, *Ollacrinus*, *Acanthocrinus*, *Ripidocrinus*, *Hadrocrinus*, *Trybliocrinus*,* and *Thysano-*

* We have not seen Geinitz's description, but judge from Zittel (Handb. der Palæont., Vol. I., p. 377) that it is a doubtful or imperfectly defined genus.

*crinus*. S. A. Miller in 1889 added *Lyriocrinus*, and adopted Lyon's name *Goniasteroidocrinus* in place of *Ollacrinus*. He amended this in the following year by leaving out the monocyclic *Hadrocrinus*, and adding *Archæocrinus* and *Raphanocrinus*.

To the genera which we arranged under this family in 1885,* we add the genus *Diabolocrinus*, which we have proposed for a species that had been previously referred by us to *Archæocrinus*.

The Rhodocrinidæ are nearest related to the Thysanocrinidæ, but are readily distinguished by the complete lateral separation of the radials † by the interradials; the radials of the Thysanocrinidæ being in lateral contact except at the anal side. The marked asymmetry in the ventral disk, so characteristic of the latter family, is not observable in the Rhodocrinidæ, in which the whole calyx, as a general rule, is remarkably symmetrical.

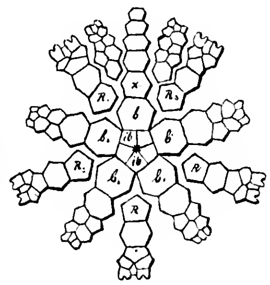


Fig. 10. — *Rhodocrinus*.

The family has a great stratigraphic range, extending from the Lower Silurian to the middle of the Carboniferous and becoming extinct in the Keokuk group. The ancestral type is probably *Archæocrinus* in the Trenton group, of which *Diabolocrinus* is an offshoot. The evolution of these forms through *Lyriocrinus* in the Niagara, *Thylacocrinus* and *Ripidocrinus* in the Devonian, to the profusely developed *Rhodocrinus* in the Carboniferous, is by easy gradations. Nor is the step from *Rhodocrinus* to the highly specialized *Gilbertsocrinus* a difficult one, because there are transition forms in which the characters of the two genera are to a great extent merged. *Raphanocrinus* in the Trenton, and *Anthemocrinus* from the Upper Silurian of Gotland, apparently represent variations toward the Thysanocrinidæ.

The Rhodocrinidæ are by far the most important dicyclic family of the Camerata, being composed of ten genera and fifty-four species, of which thirty-six are from America, and eighteen from Europe.

* Revision, Part II., pp. 96 to 99. (Proceed. Acad. Nat. Sci. Phila., pp. 318-321.)

† There is an occasional exception to this in the genus *Lyriocrinus*, where the radials are sometimes connected by a narrow strip, except at the anal side. This occurs quite frequently in *L. dactylus* from the Niagara of New York; while in *L. melissa*, *L. juvenis*, and an undescribed *Lyriocrinus* from Dudley, England, the radials are widely separated.

In the descriptions of the Rhodocrinidæ, the plate which is interposed between the radials is called the first interradial as a matter of convenience, and those following it in the dorsal cup interbrachials, although, as elsewhere explained, they all belong undoubtedly to the same system of plates.

## RHODOCRINUS Miller.

1821. Miller (in part); Nat. Hist. of the Crinoidea, p. 106.
1835. Agassiz; Mem. Soc. Sci. Neuchat., Vol. I., p. 196.
1841. Müller (in part); Monatsber. d. Berlin. Akad., p. 209.
1843. Austin; Ann. and Mag. Nat. Hist., Vol. X., p. 109.
1850. D'Orbigny; Prodr. de Paléont., Vol. I., p. 104.
1853. De Koninck and Le Hon (in part); Recher. Crin. Carb. Belg., p. 103.
1855. Roemer (in part); Leth. Geogn. (Ausg. 3), p. 240.
1855. (?) Müller (Wirtgen and Zeiler); Verh. Naturhist. Verein f. Rheinl., Vol. XII., p. 11.
1857. Pictet; Traité de Paléontologie, Vol. IV., p. 314.
1858. Hall; Geol. Rep. Iowa, Vol. I., Part II., p. 556.
1861. Hall; Bost. Journ. Nat. Hist., Vol. VII., p. 322.
1868. Meek and Worthen; Geol. Rep. Illinois, Vol. III., p. 476.
1875. Grenfell; Proceed. Bristol Naturalists' Soc., Vol. I., Part III., p. 480.
1879. Zittel; Handb. d. Palæontologie, Vol. 1., p. 376.
1881. W. and Sp.; Revision Palæocr., Part II., p. 209 (Proceed. Acad. Nat. Sci. Phila., p. 383).
1883. Worthen; Geol. Rep. Illinois, Vol. VII., p. 305.
1885. Quenstedt (in part); Handb. d. Petrefactenkunde (Ausg. 3), p. 958.
1889. W. and Sp.; Geol. Rep. Illinois, Vol. VIII., p. 180.
1889. S. A. Miller; N. Amer. Geol. and Palæont., p. 277 (not Fig. 417).

(Not *Rhodocrinus* Goldf., 1826, Petref. Germaniæ, Vol. 1., p. 212; nor McCoy, 1844, Carbonif. Foss. Ireland, p. 180; nor F. Roemer, 1851, Verh. Naturh. Verein f. Rheinl., Vol. VIII., p. 358; nor Billings, 1859, Geol. Rep. Canada, Decade IV., p. 61; nor Lyon, 1861, Proc. Acad. Nat. Sci. Phila., p. 409; nor Hall, 1863, Trans. Albany Inst., Vol. IV., p. 198, and 1876, 1st edit. of 28th Rep. N. Y. State Mus. Nat. Hist., p. 139; nor Schultze, 1867, Mon. Echin. Eifl. Kalkes, p. 53; nor White, 1880, Proc. United States National Mus., p. 259.)

Syn. *Acanthocrinus* F. Roemer, 1850. Neues Jahrb. f. Mineralogie, p. 79; Müller, 1855, Verhandl. Naturh. Verein, Vol. XII., p. 8; Hall, 1862 (Subgenus of *Rhodocrinus*), 15th Rep. N. Y. State Cab. Nat. Hist., p. 125.

Calyx more or less globose, the dorsal cup generally somewhat flattened or concave at the base, and constricted in the upper part. Plates flat or convex, nodose or spiniferous, their surfaces smooth or striated. Infrabasals five, small, sometimes merely occupying the bottom of the columnar concavity. Basals five, large, all truncated at the upper end. Radials, as a rule, larger than the costals, but smaller than the basals. Costals two, not unfrequently coalesced, so as to form practically a single plate. Distichals free in part; rarely more than one, and never exceeding three, take part in the calyx. Arms arranged in pairs and bifurcating; biserial, either directly from the calyx up, or from the last bifurcation; joints short; the pinnules in contact. The first interradial plate is followed by several rows of interbrachials, the second row consisting either of two or three pieces. When there are two plates at the regular sides, the anal side has always three, but when the former has three, there is no additional plate at the anal side. Ventral disk narrow, rising but little above the dorsal cup; composed of irregularly arranged plates, none of which can be recognized as orals. Disk ambulacra subtegminal. Anus excentric, sometimes marginal. Column round; the axial canal pentagonal or stelliform; the internodes frequently consisting of but one joint.

*Distribution.* — *Rhodocrinus* first appears in America in the Hamilton group; it attains its climax in the Kinderhook and Burlington beds, and becomes extinct at the end of the Keokuk epoch. Specimens, as a rule, are rare. In Europe the genus occurs in the *Rheinisch Uebergangsgebirge*, and it is represented by several species in the Mountain limestone.

*Type* of the genus: *Rhodocrinus verus* Miller, from the Carboniferous of England.

*Remarks.* — *Rhodocrinus verus,* according to J. S. Miller, occurs in the Mountain limestone of Yorkshire, and also in the Wenlock limestone of Dudley, England, and it was said to have three basal plates. Miller confounded two very different types, which have since been recognized as distinct genera. The Carboniferous form, which took Miller's specific name, is universally regarded as the type of the genus *Rhodocrinus*, having five infrabasals instead of three, and biserial arms; the Silurian form from Dudley, with three infrabasals and single arm joints, was described by Phillips as *Sagenocrinus expansus.*

The genus *Rhodocrinus*, as we understand it, includes species with smooth, nodose, and spiniferous plates. For a certain species with spinous plates from the Devonian, Roemer proposed the genus *Acanthocrinus*. We have carefully examined the figures of *A. longispinus*, as given by Wirtgen and Zeiler,* but have failed to discover any characters by which this form can be separated even subgenerically. Spinous projections on the basals and radials occur quite frequently also among Carboniferous species in all possible variations. It is possible that "*Rhodocrinus gonatodes*" Müller belongs to Oehlert's new genus *Diamenocrinus.*

We have referred *Rhodocrinus microbasilis* and *R. pyriformis,* both of Billings, to *Archæocrinus; R. vesperalis* White to *Diabolocrinus; R. melissa* Hall to *Lyriocrinus; R. Halli* Lyon to *Thysanocrinus; R. stellaris* de Koninck

* Verh. d. Naturhist. Verein, Jahrg. XII., Tab. II.

and Le Hon to *Gilbertsocrinus*. The following species are too little known to be recognized: *R. spinosus* Hall, *R. gracilis* Hall, *R. varsoviensis* Hall, and *R. rectus* Hall.

### Rhodocrinus Wortheni Hall.

*Plate XI. Fig. 6, and Plate XII. Figs. 7a, b, c.*

1858 Hall; Geol. Rep. Iowa, Vol. I., Part II., p. 556, Plate 9, Figs. 8*a*, *b*, *c*.
1881. W. and Sp.; Revision Palæocr., Part II., p. 213.

A small species. Calyx depressed-globose, a little concave at the bottom; plates delicate, flat and perfectly smooth. Infrabasals of moderate size, the tips slightly projecting beyond the column; forming a pentagon. Basals very large, a little wider than long. Radials nearly as large as the basals, angular below, narrowly truncated above; their lateral faces parallel. Costals two, generally anchylosed, the two together smaller than the radials, and only half their width; the first quadrangular. Distichals $2 \times 10$ in the calyx, those of the lower row nearly as large as the costals, the upper smaller, and excavated to form the arm bases, which do not project. Ambulacral openings small, slitlike, directed upwards, and arranged in pairs around the disk. Arms delicate and cylindrical; they branch twice above the calyx, and are uniserial to the first bifurcation, then turning into biserial, with short interlocking pieces. The five plates interposed between the radials are considerably smaller than the basals, and but little larger than the two succeeding interbrachials, which are followed by two rows of two small plates. At the anal side, the first interradial plate is larger than those of the regular sides, and followed by three plates. Ventral disk very small, and following the general curvature of the calyx. Column small, round; the upper joints rounded at their edges; the axial canal minute.

*Horizon and Locality.* — Lower Burlington limestone, Burlington, Iowa.

*Type* in the Illinois State collection, Springfield.

*Remarks.* — Specimens apparently of this species, are found in the Waverly group of Cuyahoga Co., O., as natural moulds; the calyx, however, appears to be more depressed, and larger in proportion to the length of the arms. Similar specimens, but decidedly more urn-shaped, occur in the Burlington beds of Lake Valley, New Mex., for which we propose the name *Rhodocrinus Wortheni*, var. *urceolatus* (Pl. XII. Figs. 8, *b*). The typical form resembles *R. watersianus* W. and Sp., and *R. Wachsmuthi* Hall; from which it differs in the mode of branching of the arms, and the fact that the latter has convex calyx plates; also in its basal concavity being much deeper, the column larger, and calyx higher.

**Rhodocrinus Wortheni,** var. **urceolatus** W. and Sp.

*Plate XII. Figs. 8a, b.*

Differing from the typical form of *R. Wortheni* in the form of the calyx, which is urn-shaped instead of globular, higher than wide and rounded at the bottom, while that is flattened. The infrabasals are convex, and on a level with the basals. The greatest width of the calyx is across the first costals, whence it contracts rapidly to near the arm bases, which slightly project outward, giving to the tegmen a decidedly pentangular outline. Ventral disk almost flat, wider than in the typical form, and the plates less numerous. Anus subcentral, and not protuberant. The plates of the calyx flat and without ornamentation.

*Horizon and Locality.* — Age of the Lower Burlington limestone, Lake Valley, New Mexico.

*Types* in the collection of Wachsmuth and Springer.

**Rhodocrinus watersianus** W. and Sp.

*Plate XII. Fig. 9.*

1889. W. and Sp.; Geol. Rep. Illinois, Vol. VIII., p. 184, Plate 17, Fig. 16.

A small species of the type of *Rhodocrinus Wortheni*, from which it differs in the more concave base, the proportionally smaller size of the basals, in the more elongate form of the calyx, and in the arm structure. Calyx from sub-globose to sub-ovoid, truncate at the bottom and narrowly concave; plates very slightly convex, and without ornamentation.

Infrabasals small and concealed by the column. Basals moderately large, their lower ends abruptly deflected inward, their upper portions curving outward and upward. Radials somewhat smaller than the basals; as wide as long. Only the proximal distichals take part in the calyx; they are followed by five to six slightly cuneate free plates, of which the upper one is axillary, and supports two arms, which remain simple. Arms twenty, rounded on the back, slender, very little tapering, and biserial from the last bifurcation; the joints moderately high and a little convex. Pinnules stout for the genus. The first interradial plate as large as the radials; followed by five to six interbrachials in two or three rows. The anal side has the same number of interbrachials, but these enclose a longitudinal row of three rather large anal plates. Ventral disk small, somewhat receding from the dorsal cup, producing an offset or groove around the margin; it is convex, and composed of small irregular plates. Column circular; the joints rounded at the edges; the nodal joints a little wider and higher. The internodes at about three inches from the calyx consist of six pieces, and the same number apparently persists throughout the rest of the column. Like most of these stems, it tapers considerably downward, and near the distal end is provided with comparatively stout cirri or rootlets, irregularly given off from the sides.

*Horizon and Locality.*—Kinderhook group, Le Grand, Marshall Co., Iowa.

*Types* in the collection of Wachsmuth and Springer.

### Rhodocrinus coxanus Worthen.

*Plate XIII. Figs. 6 and 7.*

1883. Worthen; Geol. Rep. Illinois, Vol. VII., p. 305, Plate 28, Fig. 7.
1885. W. and Sp.; Revision Palæocr., Part III., p. 99.
Syn. *Rhodocrinus polydactylus* Worthen; 1883, Geol. Rep. Illinois, Vol. VII., Plate 27, Fig. 5.

The two specimens figured by Worthen as *Rhodocrinus coxanus* and *R. polydactylus* are too much crushed and distorted to admit of critical comparison or satisfactory description. Both appear to have smooth plates, and these, so far as we can ascertain, are arranged substantially in the same way; but *R. polydactylus*, according to Worthen's figure, has an additional bifurcation in one of the ray divisions, *i. e.*, five arms to the ray. Whether this is a persistent character cannot be ascertained from the specimens, and until this is proved we prefer to regard *R. polydactylus* a synonym of *R. coxanus.*

*Horizon and Locality.*— Upper part of the Geode bed in the Keokuk group; Hamilton, Ills.

*Types* in the collection of L. A. Cox of Keokuk.

### Rhodocrinus Wachsmuthi Hall.

*Plate XIII. Figs 5a, b, c, d, and Plate XV. Fig. 7.*

1861. Hall; Prelim. Descr. of New Spec. of Crinoidea, Albany, p. 18.
1881. W. and Sp.; Revision Palæocr., Pt. II., p. 213.

Somewhat larger than the three preceding species. Calyx subovoid, flattened at both poles, the proximal end abruptly and deeply impressed, forming a circular pit, which is but partly filled by the upper joint of the column. Plates without ornamentation, a little convex, the suture lines slightly grooved.

Infrabasals small, concealed by the column. Basals as large, or even larger than the radials, their lower ends bending abruptly inward to take part in the pit, the upper portions curving gently outward and upward. Radials heptagonal, a little wider than long, and twice as large as the costals, which are quite narrow. Distichals free from the first up; the upper faces of the latter slightly excavated to form the ambulacral opening. The free distichals consist of about eight plates, which are very short; the upper one axillary, supporting two arms, of which one branches again on the eighth joint, while the other remains simple. Arms cylindrical, of nearly uniform size, biserial above the last bifurcation; the plates very short and transversely arranged. Pinnules rather stout and in contact; the joints twice as long as wide, with deep ambulacral grooves. Interradial areas not depressed; arranged: 1, 2, 3, 2, succeeded by three or four more pieces. The anal side has three plates in the second row. Ventral disk composed of but few plates; it is somewhat elevated at the margin, almost flat in the middle. Orals well defined; surrounded by two rows of rather large interambulacral pieces, which meet with the interbrachials. Anus subcentral, opening through the disk. Column round; axial canal small and stellate.

*Horizon and Locality.* — Lower Burlington limestone, Burlington, Iowa.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

### Rhodocrinus Whitei Hall.

*Plate XIII. Figs. 1a, b, c, and Plate XV. Figs. 6a, b.*

1861. Hall; Description of New Spec. Crinoids, p. 9.
1861. Hall; Bost. Journ. Nat. Hist., Vol. VII., p. 324.
1872. Hall; N. Y. State Mus. Nat. Hist., Bull. I., Plate 6, Figs. 19, 20, 21.
1881. W. and Sp.; Revision Palæocr., Part II., p. 213.
Syn. *Rhodocrinus Whitei*, var. *burlingtonensis* Hall; 1861, Bost. Journ. Nat. Hist., Vol. VII., p. 325.

The largest known American species. Calyx depressed sub-globose, a little wider than high; the lower portion flattened and formed into a deep concavity; the sides decidedly bulging to the first costals, then contracting to near the arm bases. All plates of the dorsal cup to the top of the costals of nearly the same size, all strongly convex, and without ornamentation.

Infrabasals of medium size, slightly projecting beyond the column. Basals large, lying almost horizontally, except their proximal ends, which bend abruptly inward and take part in the concavity; the upper faces broadly truncated. Radials hexagonal, about as wide as long. Costals as long as the radials, but generally a little narrower. Distichals generally represented by only one row of plates in the calyx, which are excavated at the upper faces to form the arm openings, of which there are two to the ray. Nothing is known of the arm structure. The interradial spaces are occupied by 1, 2, 3, and two large plates, followed by two or three smaller ones. The anal interradius has a few more plates in the upper rows. Ventral disk small, slightly convex, pentangular in outline, and composed throughout of small, irregular, slightly convex pieces, which increase in size as they approach the arm regions. Anus subcentral, at the end of a short tube or elongate protuberance, which gives to the disk an irregularly conical form. Column small, not filling the basal concavity; it is round, and there is an alternation of larger and smaller plates. Axial canal of medium size and stelliform.

*Horizon and Locality.* — Lower part of the Lower Burlington limestone, Burlington, Iowa.

*Types* in the University Museum at Ann Arbor.

*Remarks.* — We have examined a number of specimens of this rare species, including the types, and are of the opinion that the specimen which Hall described as var. *burlingtonensis* is a very large example of *R. Whitei*. That it has one or two additional interbrachials, that the calyx is proportionally a little shorter and the basal concavity deeper, is readily explained by extravagant growth. The species occurs in the lowest layers of the Lower Burlington limestone, and the calyx sometimes attains a size of two inches in diameter.

### **Rhodocrinus Benedicti** S. A. Miller.

1892. Advance Sheets Eighteenth Rep. Geol. Survey Indiana by Gorby, p. 15.

Calyx small and globular, except the tegmen, which is slightly conical. Dorsal cup nearly as high as wide, widest at the middle; the sides evenly rounded to the arm bases; the base concave. Plates convex, some of them angular, and the principal ones covered with radiating ridges. Suture lines distinct.

Infrabasals small, forming a flat pentagonal disk. Basals the largest plates of the calyx, highly convex in the central part, with ridges extending to adjoining plates. Radials nearly as large as the basals, but the ridges less conspicuous. First costals smaller than the second, convex; the second as large as the first. The second distichals support the free arms, which are not preserved. Interradial areas not depressed below the level of adjoining brachials; composed of the interradial plate, and about nine interbrachials, of which the upper ones are very small. The anal area has one or two additional plates. Ventral disk small; its diameter scarcely two thirds the width of the dorsal cup at the widest part; composed of numerous very small, highly convex plates. Anus subcentral. Column round.

*Horizon and Locality.* — Keokuk group; Harrison Co., Indiana.

*Remarks.* — We did not have access to the specimens to illustrate this species, and were obliged to make our description after Miller.

### **Rhodocrinus nodulosus** Hall.

*Plate XIII. Fig. 8.*

1862. *Rhodocrinus (Acanthocrinus) nodulosus* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist., p. 126; ibid., 1872, Bull. I., Plate 1a, Fig. 8.
1881. *Rhodocrinus nodulosus* — W. and Sp.; Revision Palæocr., Part II., p. 212.

Of medium size. Dorsal cup more rapidly spreading to the top of the second costals than from there to the arm bases; height and greatest width about equal; interradial and interdistichal spaces depressed. Plates convex, the surface covered with obscure radiating ridges, and the central portion in most of them produced into a small node.

Infrabasals small, but plainly visible beyond the column; the bottom somewhat depressed for the reception of the column. Basals larger than any of the other plates, longer than wide; the lateral upper faces longer than the lateral lower; the upper faces rather narrow. Radials larger than the costals; three of them pentagonal, the two posterior ones hexagonal; the costals slightly narrower and shorter. The distichals support the free arms; five to six of them take part in the calyx, of which the three lower ones are subquadrangular and twice as wide as long, the two or three succeeding ones cuneate, and slightly interlocking. The free distichals are less convex and shorter than those of the calyx; the succeeding arm plates strictly biserial, and very short. Arms rather stout at the proximal ends, but the size decreases rapidly with each bifurcation. There are two bifurcations in the free arms, and the branches are widely divergent. The large plates interposed between the radials are followed by two, three, and three interbrachials at the regular sides; while the anal side has three in the second and four in the third row. Construction of ventral disk and anus not known. Interaxillaries three or more.

*Horizon and Locality.* — Hamilton group; Canandaigua and Ontario Cos., N. Y.

*Type* in the New York State Cabinet of Natural History at Albany.

*Remarks.* — This form differs from the other American species, except *Rhodocrinus Kirbyi*, in having interaxillary plates, and also in the details of the arm structure. Our description was made from Hall's figure, and from a specimen in the collection of Prof. J. M. Clark, which is now in the New York State Cabinet.

### **Rhodocrinus Kirbyi** W. and Sp.

*Plate XII. Figs. 1a, b, c, d.*

1889. Geol. Rep. Illinois, Vol. VIII, p. 180, Plate 15, Fig. 10 and Plate 16, Fig. 3.

Calyx barrel-shaped, a little longer than wide, excavated at the bottom, slightly swelling from the middle of the basals to the middle of the second costals, thence contracting to the margin of the tegmen. In some specimens the sides are almost cylindrical. Surface of plates convex, covered with obscure ridges passing from plate to plate; those following the radial series somewhat stronger, and increasing in prominence as they approach the arm bases, so as to give to the calyx an obscurely pentangular outline.

Infrabasals concealed by the column, small, resting within a shallow concavity. Basals large; their lower margins abruptly bent inward; the middle portion forming a sort of rim on which the calyx rests. Radials smaller than the basals, about as wide as long. Costals two, of nearly uniform size, about half the size of the radials. Distichals five; the two lower ones incorporated into the calyx, smaller than the costals; the three upper ones free, very short and rounded exteriorly; the third axillary, giving off two branches, of which only the inner one branches again, generally from the third plate, giving three arms to each main division of the ray, or thirty in all, with occasionally an additional arm in one or both posterior rays. Arms cylindrical, and only tapering at the tips; they are composed of a double series of rather short, interlocking pieces, with indented suture lines which give to the back of the arms a file-like appearance. Pinnules strong, contiguous; composed of elongate joints. Interradial spaces arranged in four rows. The plates interposed between the radials smaller than these; followed by two, rarely three, interbrachials, and these by two and three others in the two succeeding rows, which gradually decrease in size upwards. Anal side wider, with three plates in the second, and generally four in the third row. Interdistichals from two to three, very small. Disk slightly convex, the interradial spaces a little depressed; constructed throughout of very small, irregularly arranged tumid plates. Anus almost central, at the end of a wart-like, somewhat conical protuberance, composed of very small pieces. Column round, from eight to ten inches long, nearly uniform for about two thirds its length, whence it gradually tapers to a fine point, with a few short cirri given off toward the end. The joints are rounded along their edges, and the nodal ones are a little the widest and longest.

*Horizon and Locality.* — Kinderhook group, Le Grand, Marshall Co., Iowa.

*Types* in the collection of Wachsmuth and Springer.

*Remarks.* — This species is one of the most abundant at the Le Grand locality, where many specimens have been obtained with crown and stem fully preserved. The specimens are invariably of a very dark color, though lying in contact with *Platycrinus* and other forms which are light colored, — sometimes almost as light as those from the Burlington rocks. This variation in color of the fossils is one of the interesting facts of that locality. The Crinoids must have been deposited there in very quiet waters; they occur in a soft, light buff limestone, and in many cases are imbedded just as they died. They occur in nests or colonies, and the genera and species are indiscriminately commingled, there being of Crinoids and Blastoids upwards of twenty-four species. It is therefore a singular fact, that while the specimens of some species are of a pure calcareous composition, and of very light color, those of others, under precisely the same conditions of fossilization, lying side by side with them and often with stems and arms intertwined, are harder, and of a very dark, brownish or even purplish grey color. The contrast between some of them is very marked, and so nearly constant for the species as to be quite a reliable feature for separating them. There are intermediate shades of color between the lightest and the darkest, but as a general thing specimens of the same species have a uniform shade. As a rule, all the species of *Actinocrinus*, *Platycrinus*, *Graphiocrinus*, *Scaphiocrinus*, *Taxocrinus* and the Blastoids, are of light color; *Dorycrinus* and *Dichocrinus* are dark, and *Megistocrinus* and *Batocrinus* rather intermediate; but while *Rhodocrinus Kirbyi* is very dark, *R. nanus* is light colored, and *R. watersianus* intermediate between them.

### **Rhodocrinus nanus** M. and W.

*Plate XI., Figs. 7a, b; and Plate XII., Figs. 2a, b.*

1866. Meek and Worthen; Proceed. Acad. Nat. Sci. Phila., p. 254.
1868. Meek and Worthen; Geol. Surv. Illinois, Vol. III., p. 476, Plate 18, Figs. *2a, b.*
1885. W. and Sp.; Revision Palæocr., Part II., p. 212.
1889. W. and Sp.; Geol. Surv. Illinois, Vol. VIII., p. 182, Plate 16, Fig. 4; and Plate 17, Fig. 15.
Syn. *Rhodocrinus sculptus* S. A. Miller; 1890, Descr. New Genera and Species of Echin., p. 42, Plate 7, Fig. 11.
Syn. *Rhodocrinus cœlatus* S. A. Miller; 1890, ibid., p. 43, Plate 7, Fig. 10.

Calyx subglobose, the sides regularly convex, except in specimens with very protuberant basals, in which they appear to be nearly straight; the base truncate and slightly impressed. The plates along the rays marked by rounded ridges, which vary somewhat in prominence. These ridges in some specimens are confined almost entirely to the radial series, giving to the calyx a pentagonal outline, but in others they run to the basals, interradials and anal plates, traversing the sutures, and passing from plate to plate. The plates are more or less convex, and their outlines well defined.

Infrabasals small, impressed, slightly projecting beyond the column. Basals large, a little protuberant, the calyx resting on their lower margins, which are rounded and form a low rim around the concavity. Radials nearly as large as the basals; the costals about of equal size, but one third smaller than the radials. Distichals generally five, of which only the first and larger one takes part in the calyx; the others which are of nearly uniform size and quadrangular, except the upper which is axillary, are free arm plates. The inner branches of the arms divide again on the third joint, and there is also occasionally a bifurcation from the outer branch in a posterior ray. The arms taper but little, are long, and biserial after the last bifurcation. The arm joints are narrower than in *R. Kirbyi*, and their backs more rounded; the pinnules stronger and less closely packed than in that species. First interradials half the size of the radials; followed by two interbrachials nearly as large; the succeeding plates considerably smaller, and their arrangement somewhat irregular. Anal interradius wider than the others, and enclosing a continuous row of anal plates, which rest upon the truncated upper face of the interradial. The first anal plate is as large as the radials, but the interbrachials at both sides of it are smaller than the corresponding plates of the other areas. Anal opening excentric, directed upwards, placed within a large protuberance, composed of rather large plates. Ventral disk convex, depressed at the interradial spaces, and constructed of small, irregular, convex pieces without definite arrangement.

*Horizon and Locality.* — Kinderhook group; Le Grand, Marshal Co., and Burlington, Iowa.

*Types* in the Museum of Comparative Zoölogy at Cambridge, and in the collection of Wachsmuth and Springer.

*Remarks.* — This species is nearest allied to *R. Kirbyi*, from which it is distinguished by its more globose form, more slender arms, by the ridge-like series of anal plates, and the absence of interaxillaries. In the Le Grand beds this species is readily identified by its color, which is invariably light; while all specimens of *R. Kirbyi* are dark colored, and those of *R. watersianus* intermediate between the two.

### **Rhodocrinus parvus** S. A. Miller.

1891. S. A. Miller; Geol. Rep. Missouri, Bull. 4, p. 39, Plate 5, Figs. 8, 9.

Closely allied to *R. nanus*, but a somewhat smaller species and the calyx more depressed. Calyx subglobose, wider than high; the plates moderately convex, and covered in exceptionally well marked specimens by obscure ridges* passing from plate to plate; suture lines distinct. Infrabasals slightly extending beyond the column. Basals the largest plates of the calyx, bending gradually upward. Radials nearly as large as the basals. The two costals together smaller than the radials, and frequently anchylosed. Distichals five, very small, only the first a calyx plate, the succeeding ones free; the upper axillary, and supporting two arms, which do not branch again. Arm openings arranged in pairs, each pair separated by a wide interspace. Arms delicate, composed of two series of deeply interlocking, cuneate pieces, the intervening sutures grooved. Pinnules not in contact laterally. The plates interposed between the radials very large, especially that of the anal side Interbrachials 2, 3, and 2, apparently also at the anal side. The ventral disk not exposed in the specimens.

*Horizon and Locality.* — Lower part of Warsaw limestone; Booneville, Mo.

*Types* in the collection of Mr. S. A. Miller.

* We are led to believe that the ridges in Miller's figures are too distinct and misleading. In five specimens in the Missouri State collection with Miller's label attached, there are no ridges at all, and the surface is smooth or slightly roughened. That this is not owing to the preservation is shown by the fact that the other parts are sharply defined.

### Rhodocrinus Barrisi Hall.

*Plate XII. Figs. 3, 4a, b, c, d; and 5a, b.*

1861. Hall; Prelim. Notice of New Spec. of Crin. (Albany), p. 9.
1861. Hall; Boston Journ. Nat. Hist., Vol. VII. (No. 2), p. 322.
1872. Hall; N. Y. State Mus. Nat. Hist., Bull. 1, Plate 6, Figs. 16, 17.
1881. W. and Sp.; Revision Palæocr., Part II., p. 212.
Syn. *Rhodocrinus Barrisi*, var. *divergens* Hall, 1861; Boston Journ. Nat. Hist., Vol. VII., p. 324; and N. Y. State Mus., Bull. 1, Plate 6, Fig. 18.

A very variable species, of the style of *Gilbertsocrinus*. Calyx forming a polyhedron, with slightly impressed faces and a node at each angle. Dorsal cup broadly truncate at the bottom, widest at the middle of the radials, whence it tapers rapidly and uniformly to the margins of the tegmen, whose diameter is from one third to one half smaller than that of the widest part of the dorsal cup, and less than the diameter at the truncated lower part. Plates highly elevated, their middle portions crowned with spine-like processes or elongate nodes, connected by well marked ridges, which traverse the sutures and meet with the nodes of adjoining plates. The nodes upon the basals are longer, attaining in very mature specimens a length of four to five mm. by two mm. wide; they are directed obliquely downward, while those from the radials, costals, and interradials point horizontally. In less mature specimens, as a rule, the nodes are comparatively smaller. The ridges connecting the basals form around the bottom of the calyx a well defined pentagon, with a shallow concavity occupying the whole width of the lower face, enclosing the infrabasals and fully one third of the basals.

Infrabasals small, but their upper angles visible beyond the column. Basals proportionally large; their upper half abruptly bent upwards so as to take part in the lateral walls, and forming a sharp edge on which the calyx rests. Radials a little smaller than the basals. Costals very small; the first less than one third the size of the radials, but twice as large as the second. Distichals eight to twelve; the plates of the first row, and sometimes those of the second, incorporated into the calyx and in contact laterally. The free distichals short, cuneate, and in large specimens interlocking; the upper one axillary, supporting two arms, of which either one or both are branching once again. Arm openings elongate; arranged in pairs; directed horizontally. Arms about twice as long as the height of the calyx; cylindrical; somewhat divergent; the plates sharply cuneate and interlocking.

Pinnules contiguous; their joints as long as two of the arm plates. First interradial followed by two rows of interbrachials of two each, except at the anal side, which has from three to four plates in the second row; the first almost as large as the radials; the succeeding ones very much smaller. Ventral disk slightly elevated, flattened in the middle; composed of fourteen to sixteen rather large convex or conical plates, indefinitely arranged. Anus marginal, directed obliquely upwards. Column short, gradually tapering; joints moderately high, the edges almost straight.

*Horizon and Locality.* — Upper Burlington limestone; Burlington, Iowa.

*Types* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — The specimen described by Hall as variety *divergens* is a very mature form of this species. In the smaller specimens the branches of the arms are less divergent.

### **Rhodocrinus Barrisi** var. **striatus** W. & Sp.

*Plate XII. Fig. 6.*

Calyx almost cylindrical, broadly truncated at the bottom, but not excavated. Plates moderately convex, without nodes. Surface covered with well defined ridges, which meet with similar ridges from adjacent plates. The ridges connecting the basals and those proceeding from the radials to the adjoining basals forming a triangle, which encloses another whose ridges are somewhat less distinct. The form and arrangement of the plates similar to those of the typical form, but the ventral disk proportionally larger, and composed of a greater number of pieces.

*Horizon and Locality.* — Upper Burlington limestone; Burlington, Iowa.

*Type* in the collection of Wachsmuth and Springer.

### **Rhodocrinus truncatus** W. & Sp. (nov. spec.).

*Plate XIII. Figs. 2a, b, c, d, e, f.*

A rather small species. Calyx wider than high, pentangular in outline, broadly truncated at both ends; the sides nearly parallel, a little wider at the arm bases. The truncation of the lower end not only extends to the greater part of the basals, but includes small portions of the radials. The base is pentangular in outline, not excavated, except the middle part very slightly for the reception of the column. Plates convex, a little tumid, with obscure ridges or angularities passing out from their margins, and meeting those of adjoining plates; the median portions perfectly smooth.

Basals and radials of nearly the same size, both bending abruptly upward, the former to three fourths their length, the others only at the lower ends. Costals one or two; together about one half the size of the radials, very frequently anchylosed, there being scarcely a specimen with two costals in all five rays. Of the distichals generally but one plate takes part in the calyx — in very large specimens sometimes two — which is as large as the second costals. Arm openings two to the ray, facing sideways. Arms unknown. Interradial spaces flattened, composed of 1, 2, 3 plates, followed by two others between the arm openings; the plate between the radials not larger than the interbrachials above; the two latter separated by a shallow depression, which gives to the arm bases a somewhat lobed appearance, and to the tegmen a pentangular outline. Anal side wider, with three plates in the second row; the plates of the median row forming a vertical ridge of five pieces, which passes up into the tegmen. Ventral disk comparatively large, almost flat; composed of about twenty slightly convex plates, of which those near the margin are the largest. Anus marginal, on top of a small protuberance.

*Horizon and Locality.* — Upper Burlington limestone; Burlington, Iowa.

*Types* in the collection of Wachsmuth and Springer.

*Remarks.* — This species resembles the two preceding, but differs essentially in the form and proportions of the calyx. In those species the calyx attains its greatest width in the lower half of the dorsal cup, and the tegmen is proportionally narrow; while in this species the calyx is widest at the bases of the arms. Besides it differs in the construction of the anal side, and in having larger costals and distichals.

### **Rhodocrinus tuberculatus** W. & Sp. (nov. spec.).

*Plate XIII. Figs.* 3, 4.

A very knobby species; somewhat larger than the preceding one. Calyx a little higher than wide; deeply excavated at the bottom; decidedly bulging at the costals, whence it contracts uniformly to the margin of the ventral disk, where the diameter is fully one third smaller — less than the width at the lower end of the dorsal cup. All plates of the calyx, basals and infrabasals excepted, extended into conspicuous angular tubercles, of which those upon the radials are longest and stoutest.

Infrabasals placed at the bottom of a concavity; forming a pentagon, of which small portions are exposed beyond the column. Basals smaller than the radials and without nodes or tubercles; they rest within the lower concavity, except their extreme upper ends, which bend slightly upwards. Radials large, forming a rim upon which the calyx rests; their tubercles quite long, rounded at the ends, and directed obliquely downward. Costals comparatively large, their tubercles connected with one another, and sometimes with those of adjoining radials and interradials by obscure ridges. Distichals one in the calyx, provided with a horse-shoe-shaped facet for the reception of the free brachials. Arm openings elongate, facing laterally; structure of the arms unknown. First interradial followed by interbrachials in succession of 2, 2, and two more between the arm openings. The anal interradius has three plates in the second and succeeding rows, but the plates are not formed into a ridge or placed in a straight line, their arrangement being rather irregular. Interdistichals one, on a level with the arm openings. Tegmen very small, flat, and of the plates only the ends of the tubercles visible from a side view; the plates large and irregularly arranged. Anal opening marginal.

*Horizon and Locality.* — Age of the Lower Burlington limestone, Lake Valley, New Mexico.

*Types* in the collection of Wachsmuth and Springer.

*Remarks.* — This species, which has the general habitus of certain forms of *Gilbertsocrinus*, differs from all other species of *Rhodocrinus* in the form of its nodes, which cover almost the whole face of the plates. The largest nodes occur on the radials, and not on the basals, those of the latter plates being often wanting altogether. It also differs in the form and greater size of the costals and distichals.

## GILBERTSOCRINUS Phillips.

1836. Phillips; Geology of Yorkshire, Part II., p. 207.
1841. Müller; Berlin. Acad. der. Wissensch., p. 209.
1849. D'Orbigny; Prodrôme I., p. 155.
1852. D'Orbigny; Cours élément., Vol. II., p. 142.
1865. Meek and Worthen; Proceed. Acad. Nat. Sci. Phila., p. 166.
1872. Hall; N. Y. State Mus. of Nat. Hist., Bull I., Plate 1*a* and Plate VI.
1873. Meek and Worthen; Geol. Rep. Illinois, Vol. V., p. 389.
1875. Grenfell; Proceed. of Bristol Naturalists' Soc., Vol. I., Part III., p. 483.

Syn. *Ollacrinus* Cumberland; 1826, Appendix to Reliquiæ Conservatæ, Plate D; 1877, Wachsmuth; Amer. Journ. Sci., Vol. XIV., p. 125; 1878, Zittel; Handb. d. Palaeont., Vol. I., p. 376; 1881, W. and Sp.; Revision Palæocr., Part II., p. 213; and Proceed. Acad. Nat. Sci. Phila., p. 387;

1885, W. and Sp.; Revision Palæocr., Part III., p. 99; and Proceed. Acad. Nat. Sci. Phila. p. 321.

Syn. *Rhodocrinus* De Kon. and Le Hon, 1853, Recher. Crin. Carb. Belg., p. 104; Roemer, 1855, Lethæa Geognost., p. 240; Pictet, 1857, Traité de Paléont., Vol. IV., p. 314; E. Billings, 1858, Canada Surv., Decade III., pp. 25 & 26; Dujardin and Hupé, 1862, Hist. natur. des Zoophytes Echinod., p. 123; Rofe, 1865, Geol. Magazine, No. 12, p. 247.

Syn. *Goniasteroidocrinus* Lyon and Casseday, 1859, Amer. Journ. Sci., Vol. XXVIII., Ser. 2, p. 233; Meek and Worthen, 1869, Proceed. Acad. Nat. Sci. Phila., p. 73; S. A. Miller, 1877, Catal. Palæoz. Foss., p. 80, and 1889, N. Am. Geol. and Palæont., p. 249.

Syn. *Trematocrinus* Hall, 1860, Suppl. Geol. Rep. Iowa, Vol. I., p. 70, and Prelim. Notice of New Spec. of Crin., p. 9; Meek and Worthen, 1860, Proceed. Acad. Nat. Sci. Phila., p. 383; Hall, 1861, Journ. Bost. Soc. Nat. Hist., Vol. VII., p. 325, and 1862, 24th Rep. N. Y. State Cab. Nat. Hist., p. 128; Meek and Worthen, 1866, Geol. Rep. Illinois, Vol. II., p. 217.

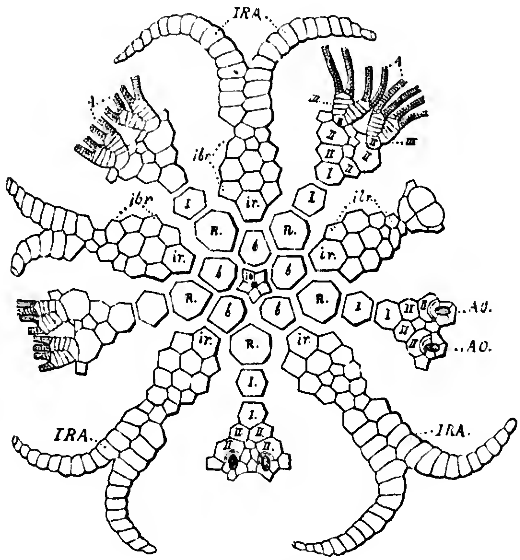



Fig. 11. — *Gilbertsocrinus.*

Ib = infrabasals, b = basals, R = radials, I = costals, II = distichals, III = palmars, A = arms, AO = arm openings, ir = interradials, ibr = interbrachials, IRA = interradial appendages.

Dorsal cup greatly exceeding the disk in size; the former elongate, more or less cylindrical; the latter flat or low-hemispherical, its margin extended into ten tubular appendages, passing outward and downward. Plates smooth or radiated, nodose or spiniferous.

Infrabasals five, small, pentagonal; forming a flat, impressed pentagon at the bottom of a concavity. Basals large, heptagonal, widely truncate above. Radials angular at the bottom. Costals two. Distichals $2 \times 10$ in the calyx; the upper ones excavated to form the lower margins of the arm openings, of which there are two to the ray, one to each main division. The arms are in clusters, delicate, branching and biserial from the last axillary; they either stand erect and fold over the disk, or are pendent, their ventral furrows exposed to view. Pinnules rather strong and closely packed together. Interradial areas large, composed of numerous plates; those alternating with the radials considerably larger and frequently nodose, the interbrachials arranged in vertical rows. Anal interradius generally not distinct in the cup.

Ventral disk nearly flat, with five pit-like interradial depressions, of which the posterior one is considerably the largest; the bottom of the pits formed by small polygonal pieces, surrounded by larger plates. In the European species, in which the pits are less conspicuous or even wanting, the disk plates differ but little in size. The outer margins of the disk are extended outward, and form ten large tubular appendages, which are pendent, in some species reaching down below the calyx. These appendages are formed either by a single row of cylindrical joints, or by three rows of plates longitudinally arranged, two of them ventrally disposed, the third dorsally; but when two of them are suturally connected, the consolidated part is composed of two and six plates respectively. The tubes are all pierced to their full length by a central canal, which, on entering the calyx, connects with the subtegminal grooves at the inner floor of the disk. In the European species, the ten appendages are free from their origin in the calyx, and those facing the same interradius are separated from each other by interradial plates. In the American forms, however, with the exception of *G. spinigerus* from the Hamilton, and *G. fiscellus* from the lower Burlington, the tubes meet in pairs at midway between two rays, and are for some distance laterally connected by a rigid suture; but, although apparently forming a single appendage, each one from the base up has its own canal, and the two canals of the same set connect with different ambulacra. The arm or ambulacral openings are located beneath the appendages; they occupy the bottom of a small, funnel-shaped pit, and are formed between the second distichals and the proximal plates of the appendages. Anus subcentral, opening out directly through the tegmen, and occupying the upper (inner) end of the posterior depression.

Orals of rather irregular arrangement, and their identification sometimes difficult in certain species.

Column circular; the nodal joints considerably wider and higher, rounded at their edges; axial canal pentalobate or stellate, the angles directed radially.

*Distribution.*—*Gilbertsocrinus* occurs in America and Europe. It first appeared in the Hamilton group, reached its climax in the two Burlington beds, and became extinct before the close of the Keokuk epoch.

*Remarks.*—The name *Ollacrinus*, the earliest name given to this form, was proposed by Cumberland in 1826, in an appendix to the Reliquiæ Conservatæ. He published no generic diagnosis or specific name, but gave an excellent figure, by which the type is easily identified. Of the plate containing this figure, however, we have been informed by the late Dr. P. H. Carpenter that only a few copies were distributed in a private way, and that no copy of it is to be found in the Library of the British Museum.* For this reason it cannot be looked upon as lawfully published, and the name will have to be given up.

Phillips proposed the genus *Gilbertsocrinus* in 1836. He included in it Cumberland's type, which he described as *G. calcaratus* (Pl. XV. fig. 5). His figures are fairly good, but the descriptions are meagre, and show no essential departures from *Rhodocrinus*. Neither does he make any allusion to the two different sets of openings, which are so well represented in his figures. The arms are described as "rounded and perforated in the centre."

De Koninck and Le Hon, in 1854, declared that *Ollacrinus* and *Gilbertsocrinus* were synonyms of *Rhodocrinus*. They probably arrived at this conclusion from their "*Rhodocrinus stellaris*," which we find to be a true *Gilbertsocrinus* (Pl. XV., fig. 4). Similar views were expressed by Roemer, Pictet, and Dujardin and Hupé.

In 1859, Lyon and Casseday described a new species from the Carboniferous of Kentucky, and made it the type of a new genus: *Goniasteroidocrinus*. The species closely resembles that figured by Cumberland and Phillips, except that the supposed arms (appendages) are suturally connected by their sides, in pairs, for some distance; while those of the British species are separate from their origin. Lyon and Casseday's specimen was in excellent preservation, the so-called arms being all in position, and it had below and between these "arms, in the interradial fields," as they state, clusters of

* We saw it in the Cambridge copy which was formerly in De Koninck's library.

from five to seven "long pendulous cilia" bearing delicate pinnules. The pinnulated "cilia" they afterwards refer with a query to arms.

Hall in 1860, without making any comparison with *Goniasteroidocrinus*, described under the new name *Trematocrinus*, a number of species from the Subcarboniferous, of undoubted generic identity with Lyon's species. He also regarded the upper appendages as arms, but doubted if they could have performed the functions of arms. He further suggested that probably the "foramina" above the secondary radials served for the protrusion of "fleshy arms or tentacles." However, a year or two later he described his *Trematocrinus spinigerus* with "summit arms" and "true arms."

In 1865, Rofe, who apparently was not acquainted with the writings of Lyon and Hall, while discussing certain morphological questions, asserted that Phillips' species of *Gilbertsocrinus* "are undoubtedly *Rhodocrini*." He also stated that *Rhodocrinus* differs from most of the other Crinoids "in the form of the arms and in the position of the ovarian apertures," and that "the arms have no grooves on the upper side, but are cylindrical, with a tubular canal through the axis, and the ovarian openings placed immediately under the base of the arms." In reply to Billings' supposition that the upper appendages might possibly be spines, he said: "their articulated structure, and the passage through the axis forbid the idea of their being spines."

Meek and Worthen, in 1866,* discriminated between *Gilbertsocrinus* and *Goniasteroidocrinus*; making the latter a section of the former. *Gilbertsocrinus* was said by them to have the "pseudo-ambulacral appendages" located directly over the interdistichal spaces, and *Goniasteroidocrinus* over the interradial ones; and they stated that these structures are not arms, that they "differ essentially from all appendages of the body in any known Crinoid, and seem to bear somewhat the same relations to the body, that the side branches of the column of *Pentacrinus* and many Palæozoic Crinoids do to the column itself." The "true arms," they say, connect with the calyx at the lower openings, which Hall described as foramina in *Trematocrinus*. They gave a description and good figures both of the true arms and the appendages.

Grenfell, in 1875, defined *Gilbertsocrinus* as follows: "Basals five; subradials five; radials three; brachials several, generally irregular; the second brachial channelled at top, and leading into an orifice which com-

* Geol. Rep. Illinois, Vol. II., pp. 219–221.

municates with the perforation in the arms; axillary plates well developed; arms round and generally set at right angles to the body." He took the upper openings, *i. e.*, the central perforation following the median line of the appendages, to be "efferent tubes," carrying off the water used for respiration, which he thinks in other groups is performed by the anal tube.

From numerous specimens in our collection, some of them with all of the two kinds of appendages preserved to their full length, we are enabled to fully confirm the opinion of Meek and Worthen that the smaller, pinnule-bearing appendages are arms, and that the stouter, tubular ones are structures unlike those of other Crinoids. What the functions of these tubes may have been can only be conjectured, but they were probably not identical with those of the cirri, as Meek and Worthen supposed; and we are inclined to think, from the fact that their canals communicate with the subtegminal galleries at the inner floor of the ventral disk, that the functions, as suggested by Grenfell, were respiratory, and that the canals performed a similar office to that of the respiratory pores of *Batocrinus* and the spiracles of the Blastoids.

Meek and Worthen, in separating the European species from the American, were probably not aware that the coalesced appendages are actually pairs of distinct tubes, each one having a canal of its own, and the canals of the same pair communicating with different ambulacra, in a way similar to that of the paired spiracles in the Blastoid genus *Pentremites*. It is in this respect exceedingly interesting that in *Gilbertsocrinus fiscellus* the posterior appendages are simple, and are widely separated by a row of anal plates, exactly as in the European species; while those of the four other sides are united at the base. The species thus represents at two of its sides the European form of the genus, and at the other three the American.

Another interesting fact in the developmental history of the genus is that in the species of the Burlington limestone the consolidated tubes are composed of the single cylindrical plates of two simple tubes united laterally by suture. In the transition beds between the Burlington and Keokuk groups appears the rare species *G. obovatus*, in which the two rows of plates composing the double tubes of its predecessors are roofed over by four more; and this character becomes constant in the Keokuk, where the genus is found quite abundant in some localities.

The genus *Rhodocrinus*, which has been so frequently confounded with *Gilbertsocrinus*, has arm openings only, the tubular appendages being unrepresented; otherwise the two genera cannot be distinguished.

### **Gilbertsocrinus tuberosus** (Lyon and Cass.).

*Plate XV. Figs. 1a, b ; Plate XVI. Figs 1 to 6 ; Plate XVII. Fig. 6.*

1860. *Goniasteroidocrinus tuberosus* — Lyon and Casseday; Amer. Journ. Sci., Vol. XXVIII., (Ser. 2), . 233.
1866. *Gilbertsocrinus* (*Goniasteroidocr.*) *tuberosus* — Meek and Worthen; Geol. Re. Illinois, Vol II., . 220, with diagrams.
1881. *Ollacrinus tuberosus* — W. and Sp.; Revision Palæocr., Pt. II., . 219.
1889. *Goniasteroidocrinus tuberosus* — S. A. Miller; N. A. Geol. and Palæont., . 250; and 1891, Adv. Sheets 17th Re. Geol. Surv. Indiana, . 51, Plate 9, Fig. 11.
Syn. *Trematocrinus robustus* Hall; 1860, Sul. Geol. Re. Iowa, . 77.

Calyx large, a little higher than wide. Dorsal cup subcylindrical, slightly constricted at the arm regions, its base deeply excavated. Ventral disk flat, with deep interradial depressions; the appendages pendent, long, and frequently branching. Plates tumid, the radials drawn out into elongate nodes or obtuse spines, directed downward.

Infrabasals small, almost completely covered by the column; forming the bottom part of the concavity, of which the basals constitute the sides, and the radials with large interradial plates between them form the rim of an inverted cone on which the remainder of the calyx rests. Radials longer than wide, considerably larger than the costals. The interradial plates large and covered with a sharp node. Costals hexagonal and heptagonal. Distichals two in the calyx, smaller than the costals, and about as wide as long. Arm openings of the same ray widely apart, separated by two or three interdistichals. Arms pendent, slender, branching, and with long pinnules; there being six ultimate arms to each arm opening. Calycine appendages in ten pairs, disposed interradially; those of adjoining rays in sutural contact to about 12 mm. from the calyx, when the pairs separate, and the two tubes take a sharp outward turn, so that their tips meet with those of adjacent pairs. Each tube is composed of three rows of plates longitudinally arranged, two of them occupying the ventral, the third the dorsal side, so that there are six rows for the distance to which they are united. The tubes generally branch once or twice; they are long, and taper gradually to their tips. Interbrachials arranged longitudinally in three series of plates of nearly equal size; the anal side not distinct. Ventral disk low-hemispherical, almost flat, the plates highly convex, those forming the interradial depressions somewhat smaller. Orals a little larger than the other disk plates, and rather irregular in their arrangement. Anus slightly excentric, forming a simple opening through the tegmen, and in most of the specimens covered by a *Platyceras equilatera* Hall. Column round and rather stout.

*Horizon and Locality.* — Keokuk group; Crawfordsville, Ind.; Hardin Co., Ky.; and Keokuk, Iowa.

*Type* in the Lyon collection.

*Remarks.* — This species is Lyon and Casseday's type of the genus *Goniasteroidocrinus.*

### Gilbertsocrinus dispansus W. and Sp. (nov. sp.).

*Plate XV. Figs. 2a, b, c, d.*

Syn. *Goniasteroidocrinus lyonanus* — S. A. Miller; Geol. Surv. Illinois, Bull. 3, p. 55, Plate 4, Fig. 1.

Of the type of *Gilbertsocrinus tuberosus*, but a smaller species, the arms less numerous, and the calycine appendages proportionally larger. Calyx somewhat depressed, wider than high, truncated at the bottom, the median portions deeply excavated. Plates convex except the radials, which are extended into elongate nodes or obtuse spines directed obliquely downward.

Infrabasals small, placed at the bottom of the concavity, and almost covered by the column. Basals rather small for the genus; their distal ends curving upwards and forming together with the median portions of the radials a rim upon which the calyx rests, while the lower portions of those plates are involved in the concavity. Radials very large, more than twice as large as the costals. Costals and distichals of nearly the same size, slightly projecting over the plates of the interradial and interdistichal areas. Interradial areas composed of 1, 3, 3, 2, 2 plates; the middle one of the second and third rows a little larger, and raised somewhat above the level of the two outer ones; the anal side not distinct. Interdistichals three, longitudinally arranged. Tegmen flat, with five deep interradial depressions, of which the posterior one is twice as large as the others; all of them oval in outline, and surrounded by a series of nodose pieces. The anal opening occupies the inner end of the larger depression, and in perfect specimens appears to be closed by a pyramid of numerous very minute pieces. The smaller depressions are paved by four or five larger plates of irregular form. The appendages are given off in pairs from the calyx, being for quite a distance laterally connected; they are very large, slightly pendent, and each pair is composed of six longitudinal rows of transverse, slightly nodose pieces, alternately arranged. They separate at the eighth or tenth plate, when they bend abruptly outward in opposite directions, and each simple tube is thence composed of three rows of pieces. Arms short, pendent, and recumbent; they are composed of two rows of plates, and pinnulated. There being six arms to each arm opening, three to each main division, but rarely more than three are exposed to view, the others being covered by the appendages.

*Horizon and Locality.* — Keokuk group; Indian Creek, Montgomery Co., Ind., where it has been found in splendid preservation.

*Types* in the collection of Wachsmuth and Springer.

### Gilbertsocrinus obovatus Meek and Worthen.

*Plate XVII. Figs. 4a, b.*

1869. *Goniasteroidocrinus obovatus*—Meek and Worthen; Proceed. Acad. Nat. Sci. Phila., p. 76; and 1873, Geol. Rep. Illinois, Vol. V., p. 391, Plate 4, Fig. 6.
1881. *Ollacrinus obovatus*—W. and Sp.; Revision Palæocr., Pt. II., p. 219.

Calyx urn-shaped; basal concavity deep, but narrower than in any of the other species; the sides of the dorsal cup convex, constricted at the arm bases; greatest width across the second costals; ventral disk perfectly flat. Plates without ornamentation, strongly convex, and of rather uniform size.

Infrabasals small, forming together with the lower part of the basals an inverted cup. Basals larger than any other plates of the calyx, bending abruptly upwards and exposing two thirds of their surfaces in a side view. Radials a little longer than wide, slightly larger than the costals, the lower faces distinctly angular; the interradial plates considerably smaller. Distichals two, larger than the adjoining interbrachials; the second smaller than the first. Arm openings proportionally small, at the bottom of a shallow pit. Calycine appendages confluent at the proximal end, and interradially disposed. Each pair, before separation takes place, is composed of six rows of plates, and each tube pierced by a moderately large central canal. Length of appendages unknown, as is also the form and construction of the arms. Interradial areas elliptical, arched by the distichals and the plates supporting the appendages; they are composed of about thirteen plates; arranged: 1, 3, 3, 3, 3, or 1, 3, 3, 2, 2, with slight variations at the anal side. Interdistichals six to eight, the first touching the axillary distichal. Plates of the ventral disk rather large and strongly convex; the interradial depressions small, embracing only one or two pieces. Orals not distinct from the other plates. Anal opening almost central. Column round, filling nearly the whole width of the basal concavity; axial canal small and pentangular.

*Horizon and Locality.* — Highest part of the Upper Burlington limestone, Burlington and Pleasant Grove, Iowa. Rare.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — In this and the two preceding species, which were the last survivors of the genus, the individual tubes are constructed of three rows of plates instead of a single one as in all others. This species, however, differs essentially from all others in the form of the calyx. While in *G. tuberosus* and similar forms the basals form the sides of the lower concavity, they are placed in *G. oboratus* at the sides of the dorsal cup, which is decidedly convex in the latter, but flat or even concave in the former.

### Gilbertsocrinus typus (Hall).

*Plate XIV. Figs. 1, 2, 3, and Plate XVII. Figs. 7a, b.*

1859. *Trematocrinus typus* — Hall; Suppl. Geol. Rep. Iowa, p. 73.
1872. *Gilbertsocrinus* (*Trematocrinus*) *typus* — Hall; Bull. Museum Nat. Hist., Plate 6, Fig. 13.
1873. *Goniasteroidocrinus typus* — Meek and Worthen; Geol. Rep. Illinois, Vol. V., p. 390.
1881. *Ollacrinus typus* — W. and Sp.; Revision Palæocr., Pt. II., p. 219.
1889. *Goniasteroidocrinus typus* — S. A. Miller; North Amer. Geol. and Palæont., p. 250.
Syn. *Trematocrinus papillatus* Hall; Suppl. Geol. Rep. Iowa, Vol. I, p. 76.

Calyx broadly concave at the base, somewhat inflated at the middle, contracted near the top, spreading above into a projecting rim around the upper margin. Ventral disk low-hemispherical or slightly convex. Basals, radials, and interradials produced into sharp central spines or elongate nodes; all other plates convex and slightly tumid.

Infrabasals comparatively large, forming a pentagon, of which the greater part is exposed beyond the column. Basals very large, curving so that the lower halves of the plates rest within the columnar concavity, the upper forming a part of the lateral walls of the dorsal cup; their spines directed downward, while those of the other plates are directed outward. Radials much larger than the costals: the interradials one half smaller, but larger than the interbrachials. First distichal smaller than the second, the latter higher and axillary, supporting two arms, which branch from the third palmar, and again on one side from the third post-palmar, making a cluster of arms to each opening. Arms pendent, long and delicate, uniserial to the last bifurcation, when the plates become cuneate and interlock. Pinnules well proportioned. The calycine appendages pendent, unusually stout and long, and composed of cylindrical joints whose apposed faces are striated. The joints grow longer as they decrease in width, and at the end of the tubes are twice as long as wide; they are thicker in the middle than at the ends, and the median part is marked by a transverse row of little nodes. The tubes of adjacent ambulacra are united to their sixth or seventh joints, and the plates meet alternately by a zigzag suture. Interbrachials: 3, 3, 3, 3, 2 — exceptionally two in the first row — the upper row abutting against the appendages. The anal side has an additional plate in the second row. Interdistichals about six to each area. Ventral disk pentangular in outline, with five interradial depressions; the posterior one, which contains the anus, larger; the plates of nearly uniform size and all convex. Orals undeterminable. Anus more excentric than in the preceding species. Column large and round; the nodal joints higher and wider, their edges, like those of the intervening joints, slightly rounded. Axial canal sharply stellate.

*Horizon and Locality.* — Upper Burlington limestone, and Burlington and Keokuk Transition bed; Burlington and Pleasant Grove, Iowa.

*Type* in the Worthen collection.

*Remarks.* — We regard Hall's *Trematocrinus papillatus* as a mere variation of this species; the spines of the plates being shorter and the calyx more robust. In the Revision, Part II., p. 219, we erroneously placed it as a synonym under *Gilbertsocrinus tuberculosus.*

## Gilbertsocrinus tuberculosus (Hall).

*Plate XVII. Figs. 5a, b, c.*

1859. *Trematocrinus tuberculosus* — Hall; Suppl. Iowa Geol. Rep., Vol. I., p. 75.
1881. *Ollacrinus tuberculosus* W. and Sp.; Revision Palæocr., Part II., p. 219.
1889. *Goniasteroidocrinus tuberculosus* — S. A. Miller; North Amer. Palæont., 250.

In the form of calyx and arrangement of plates, this species closely resembles the preceding one, but the arms are erect instead of pendent, the appendages much shorter, and they taper rapidly to a point. Plates strongly convex or slightly nodose, the surfaces smooth.

Infrabasals placed at the bottom of a shallow concavity, which is formed by the lower half of the basals, the upper half curving upwards, and taking part in the lateral walls of the calyx. Basals and radials considerably larger than any of the succeeding plates. Costals fully one half smaller than the radials. Distichals 4×10; the two lower, which are placed in the calyx, as large as the costals; the two upper shorter and free. There are four arms to each arm opening, the upper bifurcation taking place from the third plate. Arms rather stout and long for the genus; they are erect, biserial from the last axillary, and have closely set pinnules. Calycine appendages small and short; directed outward, almost at right angles to the calyx. They are composed of single joints, of which the four or five proximal ones of adjoining rays are truncated laterally on apposed sides, and connected with one another by rigid suture; the plates interlocking. After separating, the two tubes taper rapidly, and terminate at the end of the fourth or fifth joint. The number and arrangement of the interradial plates is quite variable; but in the majority of specimens the plate between the radials is succeeded by three plates; some, however, have but two, except at the anal side which always has three; there are two or three in the next row, exceptionally four at the anal side. Interdistichals five to six. Ventral disk low-convex, with well defined interradial pits; the posterior one larger, and containing the anus. Column round; axial canal sharply stellate.

*Horizon and Locality.* — Upper Burlington limestone; Burlington, Iowa.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — Readily distinguished by the upright arms, and short, rapidly tapering tubes.

### **Gilbertsocrinus reticulatus** (Hall).

*Plate XVII. Figs. 1a, b.*

1860. *Trematocrinus reticulatus* — Hall; Descr. New Spec. Crin., p. 9; also Boston Journ. Nat. Hist., Vol. VII., p. 325.
1881. *Ollacrinus reticulatus* — W. and Sp.; Revision Palæocr., Part II., p. 219.
1889. *Goniasteroidocrinus reticulatus* — S. A. Miller; North Amer. Geol. and Palæont., p. 250.

Calyx small compared with the preceding species, about as wide as high; dorsal cup urn-shaped with convex sides and a wide and deep concavity at the bottom; ventral disk almost flat. Plates slightly convex, their surfaces marked by a series of obscure ridges, radiating from the centre of the plates to adjoining ones. The ridges follow the rays, and those passing from the radials to the basals are stronger and somewhat higher; the latter producing around the basal concavity at the bottom of the calyx the well defined figure of a pentagon with convex sides.

Infrabasals forming a pentangular disk, of which the angles project quite plainly beyond the column. Basals large, their upper ends curving abruptly upwards, the lower portions of the plates to two thirds their length, together with the infrabasals and the extreme ends of the radials, forming a wide and deep inverted basin. Radials as large as the basals, a little longer than wide. Costals nearly one half smaller than the radials, both of the same size, and higher than wide. Distichals 2 × 2 in the calyx, nearly as large as the costals; the upper excavated to form the arm openings, which are large and circular. Appendages composed of single circular joints; the proximal ones in contact laterally. Their length and the construction of the arms unknown. Interradial spaces wide, elliptical; the plates between the radials smaller than the costals; the interbrachials arranged in rows of three and two plates, which decrease but little in size upwards. The anal interradius apparently not distinct. Interdistichals one. Column round, composed near the calyx of very short joints; the edges of the nodal ones knife-like.

*Horizon and Locality.* — Lower Burlington limestone; Burlington, Iowa, and Sedalia, Mo.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

### **Gilbertsocrinus fiscellus** (Meek and Worth.).

*Plate XVII. Figs. 2a, b, c, d.*

1860. *Trematocrinus fiscellus* — Meek and Worth.; Proceed. Acad. Nat. Sci. Phila., p. 383.
1865. *Gilbertsocrinus (Goniasteroidocr.) fiscellus* — Meek and Worth.; ibid., p. 167.
1866. *Gilbertsocrinus fiscellus* — Meek and Worth.; Geol. Rep. Illinois, Vol. II., p. 222, Plate 15, Fig. 5.
1881. *Ollacrinus fiscellus* — W. and Sp.; Revision Palæocr., Part II., p. 219.
1889. *Goniasteroidocrinus fiscellus* — S. A. Miller; North Amer. Palæont., p. 250.

A small species, smaller even than *G. reticulatus*, which it resembles in general form; but the sides of the calyx are straighter, the basal concavity narrower, and the ridges upon the plates less conspicuous.

Infrabasals very small, covered by the column. Basals hidden almost completely within the lower cavity, so that the radials and first interradials form the lower ring of plates visible from a side view. Costals as long as wide, and but little smaller than the radials. The second distichals support the free arms, of which the first joint is short and quadrangular. The arm openings of the same ray are placed closer together than in any other American species, and the tubes bordering the anal interradius are simple, with several interradial plates interposed between them; while those of the other sides, on the contrary, are united in pairs. Nothing further is known of the appendages and arms. Interradial areas arranged: 1, 3, 3, 3, 3, 2; the lower plate somewhat larger. The anal side generally has five plates in the third, fourth, and fifth rows, and two small plates above. Interdistichal areas composed of a rather large plate, succeeded by four or five smaller ones. Ventral disk almost flat, with deep interradial depressions. Some of the plates are larger and more convex, but none of them are referable to orals. Anus subcentral, on top of a small protuberance. Column unknown.

*Horizon and Locality.* — Lower Burlington limestone; Burlington, Iowa.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

### Gilbertsocrinus tenuiradiatus (M. and W.).

*Plate XVII. Fig. 3.*

1869. *Goniasteroidocrinus tenuiradiatus* — MEEK and WORTHEN; Proceed. Acad. Nat. Sci. Phila., p. 75.
1873. *Goniasteroidocrinus tenuiradiatus* — MEEK and WORTHEN; Geol. Rep. Illinois, Vol. V., p. 389, Plate 11, Fig. 1.
1881. *Ollacrinus tenuiradiatus* — W. and SP.; Revision Palæocr., Part II., p. 219.
1889. *Goniasteroidocrinus tenuiradiatus* — S. A. MILLER; North Amer. Geol. and Palæont., p. 250.

The two specimens before us are considerably crushed, and their general form and the arrangement of the plates cannot be accurately determined. It is a larger species than the two preceding ones, with which it is found associated, and which it resembles in the delicacy of the plates; but in other respects it is more like *G. typus*, of a higher horizon. The surface of the plates is marked by a series of elevations, radiating from the middle of the plates to adjoining ones, which, however, are not ornamented ridges, but are produced by a folding of the plates. The basal concavity is quite shallow, and composed almost exclusively of the infrabasals.

Basals large, curving upwards and inwards, their upper lateral faces longer than the corresponding lower ones; they are extended into a sharp, slender spine rising from the centre of the plates, unlike the case of *G. typus*, in which the spines cover the whole surface of the plate. Radials very large, and mounted with similar spines as the basals. Arms given off from the second distichals; their structure unknown. Calycine appendages very long, and tapering but slightly; their joints are strictly cylindrical and devoid of ornamentation; they are arranged interradially in pairs, and those of each pair are connected laterally by zigzag sutures to the fourth or fifth joint, when they become free and diverge in opposite directions. The number of arms and the number and arrangement of interradial and interdistichal plates cannot be ascertained in the specimens.

*Horizon and Locality.* — Lower Burlington limestone; Burlington, Iowa.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — This species is distinguished from *G. typus* by the form of the spines on the basals and radials, the thinness and delicacy as well as the folding of the plates, and by the cylindrical form and smoothness of their appendages.

### Gilbertsocrinus spinigerus (Hall).

*Plate XV. Figs. 3a, b, c.*

1862. *Trematocrinus spinigerus* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist., p. 128.
1866. *Goniasteroidocrinus spinigerus* — Meek and Worth.; Geol. Surv. Illinois, Vol. II., p. 222.
1872. *Gilbertsocrinus (Trematocrinus) spinigerus* — Hall; New York State Mus. Nat. Hist., Bull. I., Plate 1a, Fig. 9 (privately distributed).
1877. *Goniasteroidocrinus spinigerus* — S. A. Miller; Cat. Amer. Palæoz. Foss., p. 80.
1881. *Ollacrinus spinigerus* — W. and Sp.; Revision Palæocr., Part II., p. 219.
1889. *Goniasteroidocrinus spinigerus* — S. A. Miller; North Amer. Geol. and Palæont., p. 250.

A small species. Calyx widest across the radials, somewhat constricted at the arm bases, expanding at the upper margin. The rays marked by broad, rounded ridges proceeding to the arm openings, and giving to the section across the costals a pentangular, and across the distichals a decagonal outline; while the section at the margin of the disk, where the appendages meet in pairs, assumes again a pentangular outline, but the angles are interradial instead of radial. The plates without ornamentation, but the radials, first costals and first interradials are extended into sharp nodes or small spines. Basal concavity deep and wide, involving the infrabasals, basals, and portions of the radials and interradials.

Infrabasals comparatively large, forming a regular pentagon. Basals large; their upper sloping faces twice as long as the corresponding lower ones; broadly truncate above. Radials of nearly the same size as the basals, and deeply wedged in between them. First costals considerably larger than the second, and but little smaller than the radials. Distichals quite small, especially the second, which is deeply excavated to form the arm openings. Calycine tubes confluent at four sides, those facing the anal side simple and separated by anal plates. The appendages are short, directed almost horizontally, and are composed of joints about as long as wide. Arms erect, rather stout, the plates cuneate; they start in pairs from the calyx, branch on the fifth plate, and again on the eighth. The plates of the interradial spaces small, except the first which is very large; it is followed by 3, 3, 3, 3, and two plates. Interdistichals three or more. Ventral disk flat, with deep interradial depressions, surrounded by small nodose plates of rather irregular arrangement. Orals tuberculous; anus excentric.

*Horizon and Locality.* — Hamilton group; Ontario Co., and Thedford, Ontario.

*Types* in the New York State Cabinet of Natural History at Albany, and in the Canada Survey Museum at Ottawa.

## THYLACOCRINUS Oehlert.

1878. Oehlert; Extr. du Bull. Soc. Géol. de France (sér. 3) Tome VII., p. 578.
1879. Zittel; Handb. d. Palæont., Vol. I., p. 375.
1881. W. and Sp.; Revision Palæocr., Part II., p. 207 (Proceed. Acad. Nat. Sci., Phila., p. 381).

Calyx large, plates convex; anal interradius distinct from the others; arms arranged in groups of four or more. Infrabasals five, small. Basals five, heptagonal; their upper faces truncated, and each plate supporting an interradial. Radials followed by two costals, and these by 2×2 distichals, which in turn support within the calyx several brachials of a third, and sometimes of a fourth order. Arms heavy, long, simple throughout, and biserial. Interbrachials numerous, arranged longitudinally in series of two or three, with additional plates at the anal side. Interdistichals very numerous, in rows of one or two; interpalmars also represented. Construction of the tegmen and position of the anus unknown. Column, so far as observed, pentangular with re-entering angles.

*Distribution.* — Devonian; France, and Hamilton group; Western New York.

*Type* of the genus. — *Thylacocrinus Vannioti* Oehlert.

*Remarks.* — *Thylacocrinus* differs from *Rhodocrinus* in having interdistichals and interpalmars; the former being very rarely, the latter never, preserved in that genus. It also differs in the arrangement of the plates of the anal side, in having four or more primary arms to the ray in place of two, and in that the arms are large and simple throughout.

### Thylacocrinus Clarkei W. and Sp. (nov. spec.).

*Plate XIII. Figs. 11a, b.*

Calyx apparently globular; the plates very gradually and uniformly decreasing in size upwards. Infrabasals small, and forming a pentagon with the points of the angles slightly projecting beyond the column; column attachment stelliform, somewhat concave, the margin surrounded by concentric striæ as in Jurassic Pentacrinidæ. Basals large, slightly curving upward. Radials as wide as high, of the same size as the costals. Distichals 2×2, a little shorter than the radials. The four lower palmars form part of the calyx, the upper are free; the fixed plates considerably highest, but decreasing in height upwards; the three proximal arm plates subquadrangular, the succeeding ones gradually turning from cuneate into biserial, meeting laterally by a zigzag suture. Arms four to each ray, simple throughout, rather strong at the bases; their length unknown. Interbrachials: 1, 2, 3, 2, *etc.*, somewhat smaller than the adjoining brachials. Anal interradius wider, with three plates in the second, and four in the third row. Interdistichals in about six ranges, arranged in pairs from the first plate up. Interpalmars three to four, arranged longitudinally in single file. Ventral disk and anal opening unknown. Column pentangular with re-entering angles near the calyx; the joints of nearly equal width; the salient angles of the nodal ones bearing a small tubercle.

*Horizon and Locality.* — Hamilton group; Canandaigua Lake, N. Y.

*Type* in the New York State Cabinet of Natural History at Albany.

*Remarks.* — The species is described from a somewhat crushed specimen, formerly in the collection of Prof. John M. Clarke of Albany, N. Y., in whose honor the specific name is given.

## **DIABOLOCRINUS** W. and Sp. (nov. gen.).

(Διάβολος, the devil; *κρίνον*, a lily).

Syn. *Rhodocrinus* (in part) — White, 1880; Proceed. National Museum, Vol. II., p. 259.
Syn. *Lyriocrinus* (in part) — S. A. Miller, 1882; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 117.
Syn. *Archæocrinus* (in part) — W. and Sp., 1885; Proceed. Acad. Nat. Sci. Phila., p. 320.
Syn. *Archæocrinus* (in part) — W. and Sp., 1885; Revision Palæocr., Part III., p. 98.
Syn. *Archæocrinus* (in part) — S. A. Miller, 1889; N. A. Geol. and Palæont., p. 225.

Calyx depressed globular, with a wide and deep concavity at the bottom, involving the infrabasals and large portions of the basals. Infrabasals five, small, but projecting beyond the column. Basals large, elongate; their upper half directed horizontally or bending upwards; the upper faces broadly truncated. Radials not in lateral contact, being separated from each other by one or more plates, which rest upon the basals. Costals two. Arms two to the ray, free from the first or second distichals; their structure unknown. Arm openings very large, directed obliquely upward, and arranged in groups.

Interradial spaces wide, composed throughout of large plates, which connect with the disk plates, or, properly speaking, pass into the disk. The large plates between the radials are frequently surrounded by small supplementary or secondary pieces, which wholly or partly isolate them from the basals, radials and costals. The second range of interradials consists of two, exceptionally three, pieces, the third of three; the latter forming part of the upper margins of the arm openings. The anal interradius, which is wider than the others, has three plates in the second, and four or more in the third row. Ventral disk depressed conical; composed of rather large plates, none of them conforming to the general arrangement of orals, which are probably unrepresented. Anus almost central, and at the end of a strong tube. Column round or indistinctly pentangular, with a large pentalobate canal.

*Distribution.* — The three species herein described come from the Trenton group of Eastern Tennessee. In the same locality we found a fourth species, but none of the specimens so far obtained are sufficiently well preserved for description.

*Remarks.* — We make our *Diabolocrinus perplexus* the type of the genus. *Diabolocrinus* has closer resemblance to *Lyriocrinus* and *Archæocrinus* than to *Rhodocrinus*, but is readily distinguished from both of them. In *Lyriocrinus* the arm facets are directed strictly upwards, the arms are single and placed in a straight line with the walls of the dorsal cup; while in *Diabolocrinus* the arms were apparently given off as armlets from tubular prolongations of the calyx, and the facets are directed obliquely outward. *Archæocrinus* has a more elongate calyx, the disk consists of minute irregular pieces, it has no anal tube, and never supplementary pieces such as we find in *D. perplexus*. The latter is a feature that reminds us of *Reteocrinus*, *Xenocrinus*, and *Acrocrinus*, in which a similar intercalation of plates takes place on a much larger scale.

### **Diabolocrinus perplexus** W. and Sp. (nov. spec.).

*Plate XI. Figs. 1a, b.*

Length of calyx as compared with its width three to two; pentangular across the arm bases; the dorsal cup more than twice the height of the tegmen; basal concavity wide and moderately deep, involving nearly the whole of the basals. Plates convex, the larger ones bearing one or more conspicuous nodes, the others a single central one.

Infrabasals completely hidden by the top stem joint. Basals large, elongate, barely seen in a side view, longitudinally grooved at the median line, which gives to the cavity a decidedly pentangular outline; the angles of the upper face truncated for the reception of supplementary pieces, which in this species are not only constantly represented but quite regular in their arrangement. Costals less than half the size of the radials. Distichals still smaller and free above the first. Arm openings in pairs; elongate. Interradials 1, 2, 3 in the dorsal cup; the first, which is nearly as large as the basals, surrounded variously by from two to four supplementary pieces, two of them abutting against the radials and basals, and two against the radials and first costals. These plates vary greatly in size, being in some specimens very minute, while they are comparatively large in others. In very large specimens, when completely developed, the first regular interradial is surrounded by six plates — including the two regular interradials of the second row — and by seven plates at the anal side. In cases in which the supplementary pieces are small and imperfectly developed, the first interradials touch the radials and basals. Tegmen composed of rather large plates without any regularity in their arrangement; the interradial portions depressed, those concealing the ambulacra quite prominent. Column small, obtusely pentangular; axial canal very large.

*Horizon and Locality.* — Trenton group, near Knoxville, Tenn.

*Types* in the collection of Wachsmuth and Springer.

### **Diabolocrinus vesperalis** (White).

*Plate XI. Figs. 1c, d.*

1880. *Rhodocrinus vesperalis* — White; Proceed. U. S. Museum, Vol. II., p. 259.
1883. *Rhodocrinus vesperalis* — White; Twelfth Ann. Rep. U. S. Geol. Surv. Terr., by Hayden, p. 129, Plate 35, Figs. 4a, b.
Syn. *Lyriocrinus sculptilis* — S. A. Miller; 1882 (not Hall 1851), Cincin. Journ. Nat. Hist., Vol. V., p. 117, Plate 3, Figs. 6a, b.
Syn. *Lyriocrinus sculptus* — S. A. Miller; ibid. (private ed., Explanation of plate).
Syn. *Archæocrinus sculptus* — W. and Sp. 1885; Revision Palæocr., Part III., pp. 96–98.
Syn. *Archæocrinus sculptus* — S. A. Miller, 1889; North Amer. Geol. and Palæont., p. 225.

Calyx depressed subglobose, pentangular across the arm bases; the basals to one third their length forming a funnel-shaped concavity, of which the infrabasals form the bottom part. Plates but very slightly convex, densely covered by wrinkles or indistinct striæ.

Infrabasals invisible beyond the column. Basals large, elongate, the proximal portions concave; the distal portions of the plates bending upwards; the faces supporting the interradials broadly truncated. Radials sometimes smaller than basals and interradials, their lower faces decidedly angular. Costals smaller than the radials; the second shorter and narrower than the first. Distichals to the height of the second plate incorporated into the calyx, the succeeding ones free; the plates short and semilunate. Regular interradials: 1, 2, 3, the first nearly as large as the basals, the upper ones considerably smaller; the supplementary pieces irregularly distributed among the interrays, or absent altogether. Tegmen as in the preceding species.

*Horizon and Locality.* — Same as last.

*Type* in the National Museum at Washington.

*Remarks.* This form was described by White in 1880 under the name of *Rhodocrinus vesperalis,* and it was stated that the specimen probably came from the coal measures, thirty miles west of Humboldt, Kans. S. A. Miller redescribed the species in 1882 as *Lyriocrinus sculptus,** giving "Tennessee" as locality, and "Niagara group" as the probable horizon. The specimens from which our figures are made were collected by one of us in 1883, from rocks of the Trenton group at Knoxville, Tenn., where they were found associated with *Hybocrinus* and other typical Trenton forms. We have compared these specimens carefully with White's type of *Rhodocrinus vesperalis* in the National Museum, and also with Miller's *Lyriocrinus sculptus* in his own collection, and not only find the various specimens specifically identical, but think it most probable that they all came from the same locality.

### **Diabolocrinus hieroglyphicus** W. and Sp. (nov. spec.).

*Plate X. Figs. 5a, b. c.*

Calyx globose; basal portions deeply depressed, forming a narrow funnel-shaped pit, of slightly pentangular outline, which encloses the whole of the infrabasals and one fourth of the basals. Arm openings directed obliquely upwards, and invisible in a dorsal view. Plates of the dorsal cup covered with numerous elongate nodes, of irregular form, which give to the surface an appearance suggestive of being densely covered with hieroglyphics. The rays are marked by conspicuous ridges following the median line of the plates, and similar ridges pass out from the centre of the radials

* It was described in the Journal of the Cincinnati Society under the name of *Lyriocrinus sculptilis;* but Miller, on finding the name preoccupied, changed it in his private edition to *L. sculptus.*

to adjoining basals, the latter forming upon the surface a well defined five-rayed star, whose salient angles alternate with the angles of the basal concavity.

Infrabasals small, and almost completely covered by the upper joint of the column. Basals large, elongate; spread out horizontally, except their lower ends, which form the sides of the funnel-shaped pit. Radials large, their lower faces sharply angular. Costals smaller than the radials; the second considerably smaller than the first. Distichals free from the second plate; very short. Arm structure unknown. Interbrachials: 1, 2, 3, 2, 1, with variations of three plates in the second, and two to four in the third ranges; the first plate large, being next to the basals the largest plate of the calyx; the plates of the second row considerably smaller, especially when there are more than two plates in that row. The supplementary interradials are less frequently represented than in the preceding species, and rarely by four plates to the interray; but there is scarcely a specimen in which there is not at least one of them introduced at one side. The plates of the third row are placed between the arm bases; the succeeding ones form part of the ventral disk. The anal side is wider and the plates more numerous; there being three or four in the second row, and four or more in the succeeding ones. Ventral disk almost as high as the dorsal cup; composed of rather large convex plates of nearly uniform size. Orals cannot be identified, the whole ventral pavement consisting of the same kind of irregularly arranged plates. Anus nearly central, extended into a strong tube. Column near the calyx apparently slightly pentangular; central canal very large and pentalobate.

*Horizon and Locality.* — Trenton group; near Knoxville, Tenn.

*Types* in the collection of Wachsmuth and Springer.

*Remarks.* — This species is distinguished from the preceding one by the different form of the calyx, the peculiar style of ornamentation, and by the irregularity in the distribution of supplementary pieces in the interradial series.

## ARCHÆOCRINUS W. and Sr.

1881. W. and Sr.; Revision Palæocr., Part II., p. 189; also Proceed. Acad. Nat. Sci. Phila., p. 363.
1885. W. and Sr.; Revision Palæocr., Part III., p. 96; Proceed. Acad. Nat. Sci. Phila., p. 318.
1883. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 217.
1889. S. A. Miller; N. Amer. Geol. and Palæont., p. 224.

Calyx large, obconical or subovate; plates smooth or variously ornamented; those in a radial direction marked along their median line by obscure, flattened ridges, which grow more conspicuous on approaching the arms. Infrabasals small, rarely extending beyond the column, and resting, as a rule, within a concavity formed by the lower part of the basals. Basals heptagonal, their upper faces truncated. Radials in three of the rays pentagonal, in the two posterior ones frequently hexagonal. When there are no palmars the three to six lower distichals take part in the calyx, and the succeeding ones are free arm plates. Arms short, slender, branching; composed of two rows of cuneiform pieces, alternately arranged and interlocking. Interradial areas constructed of numerous plates; the plate between the radials, which is much larger than the others, is followed at the regular sides by two interbrachials in the second row, at the anal side by three, but there is no median ridge or continuous row of anal plates. The upper interbrachials connect imperceptibly with the plates of the disk. Interdistichals always represented. Ventral disk, as observed in *A. desideratus*, composed of small irregular pieces, which close over the ambulacra, except near the outer margin of the integument, where their covering pieces are exposed. Column round, the edges of the nodal joints largely projecting over the internodal ones; axial canal large, pentalobate.

*Distribution.* — Probably restricted to the Trenton group of America.

*Type* of the genus: *Archæocrinus lacunosus* (Billings).

*Remarks.* — *Archæocrinus* has close affinities with *Rhodocrinus*, and it is somewhat difficult to point out the structural differences. The calyx of the former is relatively larger, the arms shorter, and it has but two interbrachials in the second row; while *Rhodocrinus*, as a rule, has three plates in the second and all succeeding rows; and the anal interradius very often has the same arrangement of plates as the others.

*Glyptocrinus marginatus* Billings, which in 1881 we placed under *Archæocrinus*, proves to be a monocyclic form, and will have to be referred back to *Glyptocrinus* as a somewhat aberrant type. Whether *Rhodocrinus asperatus* Billings belongs here, cannot be ascertained from the imperfect state of the specimen. *Lyriocrinus sculptus* S. A. Miller (*Archæocrinus sculptus* W. & Sp.) is a synonym of *Rhodocrinus vesperalis* White, which has been placed under the genus *Diabolocrinus*.

**Archæocrinus lacunosus** (Billings).

*Plate X. Fig. 1.*

1857. *Glyptocrinus lacunosus* — Billings; Geol. Rep. Canada (Rep. of Progr.), p. 261, also ibid. 1859, Decade IV., p. 61, Plate 8, Figs. 3 *a–e*.
1881. *Archæocrinus lacunosus* — W. and Sp.; Revision Palæocr., Part II., p. 190.

The only known specimen is somewhat crushed, and its exact form cannot be ascertained, but it was probably subglobose. The median line of the rays is followed by ridges, which grow quite prominent upon the distichals, and the surface of the plates is completely covered by small rugose pits and wrinkles.

Infrabasals very minute, not visible from a side view. Basals unusually large, the largest plates of the calyx; their truncated upper side very wide. Radials slightly smaller than the basals, the two facing the posterior side heptagonal, the others pentagonal, all sharply angular below. Costals rather small. The three lower distichals take part in the calyx; they are small and curved like free arm plates. Arms ten at their origin, rounded, rather delicate, bifurcating once or oftener, the branches divergent, and composed of short interlocking pieces. Interbrachials large; those between the radials, which are almost as large as the basals, rise to the middle of the second distichals, and are followed by two plates in the second range, and others above; anal side wider, plates arranged: 1, 3, 4, *etc.* Column round, tapering considerably downward; the nodal joints very high, even those next the calyx, which are twice as wide as the intervening ones, and thick and rounded at the edges; the internodal joints comparatively short. At six cm. from the calyx the internodes contain five joints, and this number apparently does not increase in the lower part of the stem.

*Horizon and Locality.* — Upper part of Trenton group; Ottawa, Canada.

*Type* in the Canada Survey Museum at Ottawa.

**Archæocrinus pyriformis** Billings.

*Plate X. Figs. 3a, b.*

1857. *Thysanocrinus (Rhodocrinus) pyriformis* — E. Billings; Geol. Rep. Canada (Rep. of Progr.), p. 263
1859. *Rhodocrinus pyriformis* — E. Billings; ibid., Decade IV., p. 61, Plate 6, Figs. 1*a–d*.
1881. *Archæocrinus pyriformis* — W. and Sp.; Revision Palæocr., Part II., p. 190.

A large species. Calyx obconical or pyriform; one fourth higher than wide; greatest width across the second distichals, slightly contracting above.

Surface of plates smooth or finely granulose; the radial plates somewhat elevated along their median lines; sutures distinct, but not grooved.

Infrabasals larger than in any other known species of this genus, and plainly visible from a side view, forming a shallow cup. Basals large, a little higher than wide, upper face narrowly truncated. Radials and costals of similar size, the former pentagonal, the two costals hexagonal, except in the posterior rays in which the second is heptagonal. Distichals to the height of the sixth plate incorporated into the calyx, gradually decreasing in height; the first as large as the second interbrachials, the upper one resembling a good sized arm plate. Arms short, delicate, twice bifurcating; composed from their bases up of small triangular interlocking pieces. Interbrachials: 1, 2, 2, 2, *etc.*, rarely 1, 2, 3, 3, the lower plate heptagonal, larger than the radials; at the anal side there are three plates in the second and all succeeding rows. Interdistichals nine or more, rather large. Structure of ventral disk and anus not known. Column circular, slightly tapering; in the upper part of the stem the nodal joints project, but further down have the same size as the others.

*Horizon and Locality.*—Trenton limestone; Montreal, Canada.

*Types* in the Canada Survey Museum at Ottawa.

### **Archæocrinus microbasalis** Billings.

*Plate X. Figs. 2a, b, c.*

1857. *Thysanocrinus (Rhodocrinus) microbasalis* — E. Billings; Geol. Rep. Canada (Rep. of Progr.) p. 264; also ibid., Decade IV., p. 63, Plate 6, Fig. 2.
1881. *Archæocrinus microbasalis* — W. and Sr.; Revision Palæocr., Part II., p. 190.

Smaller than the preceding species, the arms proportionally longer. Calyx obconical, truncated at the lower end, sides slightly convex. Surface beautifully ornamented with parallel, radiating striæ, proceeding from the middle of the plates to adjoining ones, and broad, rounded ridges, starting from the middle of the radials and passing up the costals and distichals into the free arms.

Infrabasals minute, forming a pentagon, which rests within the basal concavity and is covered by the column. Basals large, heptagonal, more than two thirds of the plates visible from a side view, the lower end bent inward and forming, together with the infrabasals, a good sized concavity, with a thickened rim around the edge; the upper faces narrowly truncated. Radials as large as the basals, distinctly angular below; the costals somewhat smaller.

The lower distichals to the number of seven or eight take part in the calyx; they decrease rapidly in size, the lower one being comparatively large, but the fourth is but little larger than the free plates; the plates above are triangular and interlock. Arms long, rather stout at their bases, but tapering gradually to the tips where they are quite thin; they bifurcate twice or oftener, and are composed of two rows of plates with parallel faces. Regular interbrachials: 1, 2, 3, 3, followed by numerous smaller plates; the anal side has 1, 3, 3, 4, *etc.* Of interdistichals as many as fourteen pieces have been observed, the lower one resting upon the first distichals. Construction of the ventral disk and form and position of the anal opening unknown. Column round, tapering downward; the upper part composed of alternately large and small joints with angular edges; but at about three inches from the calyx the internodal joints reach the width and height of the nodal ones, and the edges lose their angularity.

*Horizon and Locality.* — Trenton limestone; Ottawa, Canada.

The figured specimens are in the collection of Mr. John Stewart of Ottawa. *Type* in the Geological Survey Museum at Ottawa.

### **Archæocrinus desideratus** W. R. Billings.

*Plate X. Figs. 4a, b.*

1885. W. R. Billings; Trans. Field Natur. Club, Ottawa No. 6.
1885. W. and Sp.; Revision Palæocr., Part III, p. 98.

A rather large species. Calyx depressed globose; basal portions deeply depressed, forming a broad funnel-shaped pit, much wider than the circumference of the stem, and deep enough to contain five or six stem joints. Plates convex, without ornamentation or other markings, except obscure elevations — a kind of broad, rounded ridges — following the median line of the rays, and branching to the basals.

Infrabasals small, hidden by the column. Basals large, twice as long as wide; the lower half of the plates forming the sides of the basal pit; the upper halves, which bend abruptly upward and outward, occupy the sides of the cup. Radials pentagonal, almost as long as wide, their lower faces forming a sharp angle, which extends down to the margin of the basal concavity. First costals hexagonal, as wide as the radials, but shorter; the second shorter and narrower than the first. Distichals 4×2, all incorporated into the calyx, and comparatively small; they are rounded exteriorly, and the two series of the same ray are so nearly in contact as to leave but a narrow space for the insertion of interdistichals. First distichals somewhat longer than the succeeding ones, which are quite short; the fourth is axillary, giving off to the outer sides a row of palmars, which are free from the third or fourth plate; to the inner side two palmars, of which the upper is axillary, and supports two arms, making three arms to each side of the ray. Arms subcylindrical, stout, very little tapering; composed at their bases of a few quadrangular pieces, followed by cuneate ones, which deeply interlock. Pinnules strong, given off nearly at right angles, and composed of short joints; the first very much stouter than the others, given off from the second distichals, and wholly or partly incorporated into the calyx. Interradial spaces wide, the upper portions rather deeply depressed. The plates of the two lower ranges very large, the first being the largest plate in the calyx. There are probably five or six rows above, but the number of plates in each row is extremely variable; the third contains variously from three to five plates at the regular sides, and from four to six at the anal side; the fourth row has as many as eight in some specimens. The first plate of the anal side is somewhat larger than those of the regular sides; it is octagonal, its upper angle being slightly truncated for the reception of a narrow anal plate, which is placed between two interbrachials. Interdistichals from one to three, longitudinally arranged. Ventral disk rather flat, composed of very small irregular pieces; the ambulacra subtegminal, except near the arm bases, but the course of the ambulacra is marked by high ridges which diverge to the arms, and form deep depressions all along the interambulacral spaces. Orals apparently unrepresented, the summit being covered by similar small plates to the rest of the disk. Anal opening subcentral, at the top of a well defined protuberance. Column round; axial canal large, pentalobate, the outer ends of the lobes widest and truncated.

*Horizon and Locality.* — Trenton limestone; Ottawa, Canada.

*Types* in the collection of Mr. Walter R. Billings, Ottawa.

## RHAPHANOCRINUS W. and Sp.

1885. W. and Sp.; Revision, Part III., p. 98 (Proceed. Acad. Nat. Sci. Phila., p. 320).
1887. Oehlert; Ann. des Sci. Géol., Tome XIX., Plate 1., Figs. 10, 11.
1889. S. A. Miller; North Amer. Geol. and Palæont., p. 277.
Syn. *Glyptocrinus* (in part) — Walcott; 1883, New Spec. Foss. of the Trenton group of New York, p. 2 (Abstr. from the 35th Rep. New York State Museum Nat. Hist.).
Syn. *Glyptocrinus* (in part) — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 37, and ibid., 1883, Vol. VI., p. 224.

Allied to *Archæocrinus*, but arms uniserial and not bifurcating. Radial ridges generally well developed. Infrabasals small, not visible from a side view, and generally completely hidden by the column. Basals large, hexagonal, the upper face truncated for the reception of the first interradials. Radials and second costals of similar form, but the former angular below, the latter angular above. Arms ten to twenty, free from the distichals or palmars according to species; they are stout, long, simple, and composed of quadrangular pieces with strong pinnules. Interbrachials and interdistichals numerous. Structure of ventral disk, and form of the anus unknown. Column large and round.

*Distribution.* — Both American species are from the Lower Silurian. Oehlert described a species from France under the name *Rhaphanocrinus Wachsmuthi,* which came from the "Dévonien inférieur," but this is apparently not a typical form.

*Type* of the genus: *Rhaphanocrinus subnodosus.*

### Rhapbanocrinus subnodosus (Walcott).

*Plate XI. Fig. 2.*

1883. *Glyptocrinus* (?) *subnodosus* — Walcott; 35th Rep. N. York State Mus. Nat. Hist., p. 208, Plate 17, Fig. 3.
1885. *Rhaphanocrinus subnodosus* — W. and Sp.; Revision Palæocr., Part III., p. 99.

Calyx of medium size, obconical; interradial areas depressed. Radial ridges well defined and marked by a small node in the centre of each plate; they pass down to the middle of the radials, where they meet with similar ridges from the two adjoining basals. The interradials have also a central node, from which obscure ridges pass out to the margins of the plates, where they meet with ridges from adjacent plates.

Infrabasals completely covered by the column. Basals very large, fully as high as wide, slightly truncate above. Radials heptagonal, larger than either one of the costals, decidedly angular below. Arms ten, rather stout, simple, the lower plates incorporated into the calyx, the second and all succeeding ones pinnule-bearing; they are composed throughout of comparatively long, quadrangular joints, with stout pinnules, placed wide apart. Interradials: 1, 2, 3, 3, and two or more rows above. Interdistichals: 1, 2. Nothing is known of the ventral disk or of the anal opening. Column round, very large.

*Horizon and Locality.* — Upper portion of the Trenton limestone; Trenton Falls, N. Y.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

### Rhaphanocrinus sculptus (Miller).

*Plate X. Fig. 3.*

1882. *Glyptocrinus sculptus* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 37, Plate I., Fig. 2.
1883. *Glyptocrinus sculptus* — S. A. Miller; ibid., Vol. VI., p. 224.
1885. *Glyptocrinus sculptus* — W. and Sp.; Revision Palæocr. Part III., p. 104.
1889. *Glyptocrinus sculptus* — S. A. Miller; N. Amer. Geol. and Palæont., p. 218.

Calyx subglobose; interradial spaces deeply depressed, especially the upper portion; section across the second costals sharply pentagonal, across the distichals decagonal. Radial ridges quite prominent, angular, stronger toward the sutures than at the median portion of the plates. Somewhat smaller ridges pass into the basals, forming deep triangular depressions along their sides. Other ridges run from the radials and brachials to the interradial plates, dividing the whole surface into numerous impressed triangular areas.

Infrabasals almost covered by the column. Basals of medium size, produced into angular processes, which point downward for a short distance along the sides of the upper stem joints. Radials and costals about as wide as long. Distichals three, almost as large as the costals. The plates of the third order support the arms, of which there are twenty; they are long, gradually tapering, and composed of quadrangular joints which become slightly cuneate in the upper parts of the arms. The four to five lower joints, which are considerably the largest and sharply angular on the outside, take part in the calyx; the succeeding ones are free, much shorter, and rounded. Pinnules long and slender. Interradial spaces deeply depressed between the distichals; the plates arranged: 1, 2, 3, 3, *etc.* The anal side, which is a little wider, has a few additional plates, but no anal ridge. Interdistichals: 1, 2, 1. Structure of ventral disk unknown. Column round, slightly tapering downwards, the nodal joints, near the calyx, wider and considerably longer than the intervening ones, but at two inches below the latter reach almost the same size.

*Horizon and Locality.* — Upper part of the Hudson River group; Warren Co., Ohio.

*Types* in the collection of I. H. Harris, Esq., at Waynesville, O.

*Remarks.* — *Rhaphanocrinus sculptus* was described as monocyclic, and referred by S. A. Miller to *Glyptocrinus*. The infrabasals are only seen as small dots around the column. The species is readily distinguished from allied forms by having knife-like ridges upon the fixed brachials; while the back of the free brachials is perfectly round.

## LYRIOCRINUS Hall.

1852. Hall; Geol. Rep. N. Y. Palæontology, Vol. II., p. 197.
1857. Pictet; Traité de Paléont., Vol. IV., p. 329.
1862. Dujardin and Hupé; Hist. Natur. des Zooph. Echinod., p. 149.
1866. Shumard; Trans. Acad. Sci. St. Louis, Vol. II., p. 379.
1867. Hall; 20th Rep. N. Y. State Cab. Nat. Hist., p. 325.
1879. Hall; 28th Rep. N. Y. State Mus. Nat. Hist. (ed. 2), p. 139.
1881. W. and Sp.; Revision Palæocr., Part II., p. 203 (Proceed. Acad. Nat. Sci. Phila., p. 377).
1881. Hall; 11th Ann. Rep. Indiana by Collet, p. 269.
1889. S. A. Miller; North Amer. Geol. and Palæont., p. 258.
Syn. *Marsupiocrinus* (not Phillips) Hall; 1843, Geol. 4th Distr. New York, p. 114.
Syn. *Rhodocrinus* (not Miller) Hall, 1863; Trans. Albany Inst., p. 198.

Calyx depressed-globose, more or less flattened to the middle of the radials; symmetry almost perfectly pentamerous; plates heavy, their surfaces smooth or finely granular; ventral disk not rising above the dorsal cup; arm openings directed upwards, placed at the upper margin of the disk. Infrabasals five, very small, abruptly and deeply depressed and concealed by the column. Basals five, of uniform size, either all hexagonal and supporting upon the truncate upper face the first interradial plate; or quite frequently one or more of them hexagonal, and angular at the top. Costals two; large. Two of the distichals enclosed in the calyx. Arms two to the ray, rising in a straight line with the sides of the calyx; simple, strong, biserial, two of the interlocking plates frequently in the calyx. Interbrachials four, in three rows: 1, 2, 1. Anal side generally not distinct, but exceptionally it has a special anal plate in the second row. Disk flat, somewhat depressed in the interradial regions; composed of a great number of slightly convex, delicate pieces, and well defined orals. Anus subcentral, probably at the end of a small tube.

Column of less than medium size, round; axial canal small.

*Distribution.* — Upper Silurian. America and Europe.

*Type* of the genus: *Lyriocrinus dactylus* Hall.

*Remarks.* — The name *Lyriocrinus* was proposed for a species from the Niagara group of Lockport, which had been described under *Marsupiocrinus*, and was supposed to have but one ring of plates beneath the radials. Another species, clearly of the same genus, was afterwards referred by Hall to *Rhodocrinus*. In the construction of the calyx *Lyriocrinus* approaches *Ripidocrinus*, which, however, differs very essentially in the arm structure. S. A. Miller's *Lyriocrinus sculptus*, which in the Revision, Part II., we placed provisionally under *Archæocrinus*, belongs to *Diabolocrinus*, and is identical with *D. vesperalis* White.

In this genus we have a good illustration of the exceptional variation from the characteristics of a group, which may be met with among individuals belonging to it. In *L. dactylus* the first interradials often touch the basals only at the anal side, while in *L. melissa*, they rest upon the basals at all five sides. Again, in the former species there is generally an anal plate between the interradials of the second row, while in *L. melissa* that plate is scarcely ever represented. Departures of this kind within a genus in respect to characters which have always been regarded as of the utmost significance for distinguishing families and genera show how idle it is to expect absolute accuracy in the separation even of very important groups.

### **Lyriocrinus dactylus** Hall.

*Plate XI. Figs. 5a, b, c.*

1843 *Marsupiocrinus dactylus* — Hall; Geol. Rep. 4th Distr. N. Y., p. 113
1852. *Lyriocrinus dactylus* — Hall; Palæont. N. Y., Vol. II., p. 197. Plate 44, Figs. 1*a*–*g*.
1881. *Lyriocrinus dactylus* — W. and Sp.; Revision Palæocr., Part II., p. 205.

Calyx semi-globose: basal regions flattened, the centre abruptly depressed for the reception of the column. Surface of plates smooth or finely corrugated. Infrabasals very small, restricted to the bottom of the columnar concavity. Basals large, four of them angular above, that of the anal side truncate. Radials wider than high, larger than the costals, slightly touching each other laterally except on the anal side. Arms ten, simple; heavy at their bases, tapering upwards to one half their former size. They are composed from the calyx up of two series of alternate plates with parallel transverse faces, and have a shallow groove along the median line; their two proximal plates incorporated into the calyx. Interbrachials: 1. 2, 1; those of the first and second rows large; the lower one almost touching the basals; the upper one smaller and somewhat inflected at the upper end, resting between the lower arm plates. Another small plate is placed between the distichals so that the arms are separated at one side by an interbrachial, and at the other by an interdistichal. The first plate of the anal side, which touches the basals, is larger, and is generally followed by three plates in the second row. Column round; composed near the calyx of moderately high, thicker, and thinner joints.

*Horizon and Locality.* — Niagara group; Lockport, N. Y.

*Types* in the American Museum of Natural History at New York.

### **Lyriocrinus melissa** (Hall).

*Plate XI. Figs. 4a, b, c, d, e, f.*

1863. *Rhodocrinus melissa* — Hall; Trans. Albany Inst., p. 198 (Abstr., p. 4).
1879. *Rhodocrinus (Lyriocrinus) melissa* — Hall; 28th Rep. N. Y. State Mus. Nat. Hist. (Mus. edit.), p. 139, Plate 15, Figs. 18-27.
1881. *Lyriocrinus melissa* — W. and Sp.; Revision Palæocr. Part II., p. 205.

Calyx depressed, nearly twice as wide as high, distinctly flattened to the top of the radials, then curving rapidly upwards until the sides of the upper part are at right angles to the truncated lower part. Basal portions forming a deep pit, which is surrounded by a pentangular rim, interradially arranged, and having a triangular node at each angle. Surface of plates flat, smooth or finely corrugated.

Infrabasals very small, concealed by the column. Basals elongate, generally truncated at the upper face, the lower half of the plates curved inward, forming the sides of the concavity, the upper half horizontal. Radials large, wider than high. Both costals hexagonal, the axillary one smaller, its upper angle truncated, supporting a small interdistichal; the sloping faces support $2 \times 2$ large distichals, which are followed by free arm plates of the same order. Arms ten, equidistant; they are stout, long, tapering, and composed of short pentagonal pieces; their pinnules long and closely arranged. Interbrachials: 1, 2, 1, 1; the first as large or larger than the radials, resting against the truncate upper faces of the basals. Anal side generally not distinct; but it has exceptionally a small additional plate in the second row. Ventral disk almost flat, barely rising above the dorsal cup. Interambulacral spaces slightly depressed; orals well developed, twice as large as any of the other disk plates, and more convex. Anus subcentral, very wide, and apparently connected with a tube. Column uniformly cylindrical, the edges of the nodal joints marked by a continuous row of small nodes.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

*Types* in the American Museum of Natural History, New York.

## MELOCRINIDÆ (ROEMER) 1855.

MONOCYCLIC. LOWER BRACHIALS, WITH WELL DEFINED INTERBRACHIALS BETWEEN THEM, FORMING A PART OF THE DORSAL CUP. RADIALS IN CONTACT ALL AROUND.

*Analysis of the Genera.*

I.

THE SYMMETRY OF THE DORSAL CUP DISTURBED BY ONE OR MORE ANAL PLATES . . . . . . . . . . . . . . . . . . . . MELOCRINITES.

A. BASALS FIVE; COSTALS TWO.

*a. First costal hexagonal.*

Arms uniserial; interbrachials and interdistichals numerous. Ventral disk composed of very small, irregular plates. Basals small . . . . . . . . . . . . . *Glyptocrinus.*

Arms biserial, basals very large, otherwise resembling *Glyptocrinus* . . . . . . . . . . . . . . . *Periglyptocrinus.*

*b. First costal quadrangular.*

Arms uniserial; interbrachials few; ventral disk composed of large plates . . . . . . . . . . . . *Stelidiocrinus.*

B. BASALS FOUR; COSTALS TWO.

*a. First costal hexagonal.*

Arms uniserial, arranged in groups; simple or bifurcating, distichals two to four, calyx of moderate size . . *Mariacrinus.*

Arms long, branching often; palmars and arm joints very short, deeply interlocking. Distichals five and upwards. Calyx very large; lower palmars partly included in dorsal cup, interbrachials very numerous . *Scyphocrinus.*

The rays extended into five tubular trunks, from which biserial arms are given off from the outer sides all the way to their tips . . . . . . . . . . . . . . . . *Melocrinus.*

C. BASALS THREE; COSTALS TWO.

Arms biserial, simple from their origin; interbrachials few, an anal plate interposed within the first range . *Macrostylocrinus.*

II.

SYMMETRY OF DORSAL CUP UNDISTURBED BY ANAL PLATES . . . . DOLATOCRINITES.

A. BASALS FOUR; COSTALS TWO.

*a. Arms biserial.*

Arms simple; arranged equilaterally around the calyx; base obconical . . . . . . . . . . . . . . . *Technocrinus.*

Arms dichotomous; basal cup inverted; interbrachials large . . . . . . . . . . . . . . . . . . *Corymbocrinus.*

B. BASALS THREE, SMALL; COSTALS TWO, THE FIRST QUADRANGULAR.

*a. Arms simple.*

Arms biserial. Dorsal cup subturbinate . . . . . . . *Patelliocrinus.**
Arms uniserial; dorsal cup depressed; interbrachials few, longitudinally arranged . . . . . . . . . . *Allocrinus.*

C. BASALS LARGE, PROBABLY THREE, ANCHYLOSED.

*a. Costals two, the first quadrangular.*

*Interbrachials few.*

Dorsal cup subcylindrical; basals and radials very large, distichals small; arms unknown . . . . . . . . *Centrocrinus.*
Calyx depressed-subglobose; basals small, interbrachials few, the first extremely large. Arms biserial and generally branching. Slit-like respiratory pores at the sides of the ambulacral openings . . . . . . . . *Dolatocrinus.*

*b. Costals one; pentangular.*

Otherwise resembling *Dolatocrinus* . . . . . . . . *Stereocrinus.*
Interbrachials numerous, basals forming an inverted cup *Hadrocrinus.*

*Geological and Geographical Distribution.*

**Number of known species.**

(Open figures indicate American; those marked ( ), European.)

| FORMATION. | | | MELOCRINIDÆ. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Melocrinites. | | | | | | | Dolatocrinites. | | | | | | | | |
| General. | American. | Approximate European Equivalents. | Glyptocrinus. | Periglyptocrinus. | Stelidiocrinus. | Mariacrinus. | Scyphocrinus. | Melocrinus. | Macrostylocrinus. | Technocrinus. | Corymbocrinus. | Patelliocrinus. | Allocrinus. | Centrocrinus. | Dolatocrinus. | Stereocrinus. | Hadrocrinus. |
| Devonian. | Hamilton. | Up. Devon. | | | | | | 3 (9) | | | | | | | 8 | 2 | |
| | Up. Helderberg. | Eifel. | | | | | | 1 (7) | | | | | | 1 | 5 | | 2 |
| | Oriskany. | | | | | | | | | 2 | | | | | | | |
| | Low. Helderberg. | Grauwacke. | | | | 2 | | 2 (3) | | | | | | | | | |
| Up. Silur. | Niagara. | Wenlock. Bohemia. Gotland. | | | (3) | 3 (1) | (1) | 5 (4) | 6 | | (6) | (7) | 2 | | | | |
| Low. Silur. | Hudson River. | | 4 | | | | | | | | | | | | | | |
| | Trenton. | | 3 | 2 | 1 | | | | | | | | | | | | |
| | Total species 95 { 54 (41) | | 7 | 2 | 1 (3) | 5 (1) | (1) | 11 (23) | 6 | 2 | (6) | (7) | 2 | 1 | 13 | 2 | 2 |

* Excluding *P. fulminatus* and *P. duplicatus*, which probably belong to *Mariacrinus*, and *P. chiastodactylus* and *P. pinnulatus*, which are young specimens.

*Remarks.*—The Melocrinidæ and Eucalyptocrinidæ are the only monocyclic families of the Camerata which have a pentagonal base, and in which the radials are in contact all around. The latter, however, depart from the Melocrinidæ so widely in their ventral structure that there is no need of further comparison. The Melocrinidæ in many respects also seem closely related to the Actinocrinidæ, which followed them in time. Indeed the

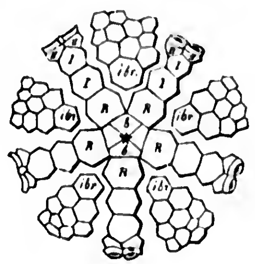


Fig. 12. *Melocrinus.*

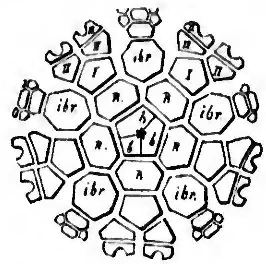


Fig. 13. *Stereocrinus.*

(For the explanation of the letters, see Fig. 11.)

superficial resemblance between the two families is often quite marked, but a Melocrinoid is always readily distinguished from an Actinocrinoid by the absence of an anal plate between the radials, and the consequent form of its base, which is pentagonal. The Melocrinidæ are among the earliest known forms of the Camerata, being already found to the extent of six species in the Trenton group, contemporaneously with the earliest Rhodocrinidæ and Reteocrinidæ. They increased in number in the Upper Silurian, but became extinct before the close of the Devonian, before the appearance of the Actinocrinidæ, so far as existing collections show. The family includes fifteen genera, of which ninety-five species are known; fifty-four from America, and forty-one from Europe.

Some of the genera referred to this family have a perfectly pentamerous dorsal cup, the posterior interradius being identical with the other four; but in others there are one or more anal plates interposed between the interbrachials, by which the pentamerous symmetry is disturbed. If this difference were well marked and constant, it would afford a basis for separation. founded on the more or less complete absence of anal structures from the dorsal cup; but this being not the case, we arranged the genera only into subdivisions with reference to it, calling those in which some trace of anal plates is found Melocrinites, and those in which they are completely absent in the cup Dolatocrinites. We find it impossible to make these divisions families, because they seem very intimately related in other respects, and shade into each other too closely, — both forms being possibly represented in species of the same genus. This is probably the case in *Hadrocrinus;* while in *Allocrinus* the first interbrachial of the posterior side is somewhat larger than the corresponding plate of the other sides.

The name Melocrinidæ was introduced by Roemer.* It was applied by him, and afterwards by Angelin,† Zittel,‡ and S. A. Miller,§ exclusively to genera with four basals, or those that were supposed to have four. *Glyptocrinus*, with five basals, although closely allied to *Mariacrinus* and *Melocrinus*, was referred by Zittel, and S. A. Miller, who substantially adopted Zittel's classification, to the Glyptocrinidæ under which they included a variety of genera, both monocyclic and dicyclic. In the classification of 1890, Miller‖ refers to the Glyptocr[illegible] the *Cupulocrinus*, *Glyptocrinus*, *Pycnocrinus*, *Schizocrinus*, and *Siphonoc[illegible]* — the first an Ichthyocrinoid; *Siphonocrinus* — a Thysanocrinoid — and both of these last dicyclic. This is the more curious because Miller is the author of *Siphonocrinus*, which he described as having three infrabasals; while he emphatically denied the presence of infrabasals in *Glyptocrinus;* and yet in establishing the families of the Crinoidea made the "presence or absence of 'subradials'" next in importance "to the number of basals," upon which his classification is principally based.

## I. MELOCRINITES.

SYMMETRY OF THE DORSAL CUP DISTURBED BY ONE OR MORE ANAL PLATES.

### GLYPTOCRINUS HALL.

1847. HALL; Palæont. New York, Vol. I., p. 280.
1854. McCOY; Synops. Brit. Palæoz. Foss., p. 56
1856. BILLINGS; Canad. Naturalist and Geologist, No. 1., p. 49.
1857. BILLINGS; Geol. Surv. Canada of 1853 to 1856, p. 256.
1859. BILLINGS; ibid., Decade IV., p. 55.
1873. MEEK; Geol. Surv. Ohio, Palæont., Vol. I., p. 30.
1874. S. A. MILLER; Cincin. Quart. Journ. Sci., p. 318.
1879. ZITTEL; Handb. der Palæont., Vol. I., p. 375.

* Lethæa Geogn., 1855 (Ausg. 3), p. 228.

† Iconogr. Crin. Succiæ, p. 10.

‡ Handb. der Palæontologie, Vol. I., pp. 368–375.

§ Amer. Palæoz. Fossils (second edit.), p. 276.

‖ American Geologist, Vol. IV., pp. 275 to 286, and pp. 340 to 357.

1881. W. and Sp.; Revision Palæocr., Part II., p. 185 (Proceed. Acad. Nat. Sci. Phila., p. 359).
1883. W. and Sp.; Amer. Journ. Sci., Vol. XXV., pp. 255 to 268.
1883. S. A. Miller; Amer. Journ. Sci., Vol. XXVI., pp. 105 to 113; and Cincin. Soc. Nat. Hist., Vol., VI., pp. 220 to 228.
1885. W. and Sp.; Revision Palæocr., Part III., p. 102 (Proceed. Acad. Nat. Sci. Phila., p. 324).
1889. S. A. Miller; North Amer. Geol. and Palæont., p. 247.

Not *Glyptocrinus* D'Orbigny, 1852; Cours élément. de Paléont., Vol. II., p. 142, nor Prodrôme, Vol. I., p. 47.
Not *Glyptocrinus* Hall, 1863, Trans. Albany Inst., Vol. IV., p. 202; nor 28th Rep. N. Y. State Mus., p. 132 = *Mariacrinus*.
Not *Glyptocrinus* Hall, 1872; 24th Rep. N. Y. State Cab. Nat. Hist., p. 206 = *Reteocrinus*.
Not *Glyptocrinus* Hall, 1872; ibid., p. 207 = *Ptychocrinus*.
Not *Glyptocrinus* Wetherby; Journ. Cincin. Soc. Nat. Hist., Vol. IV., p. 83 = *Reteocrinus*.
Not *Glyptocrinus* S. A. Miller; ibid., Vol IV., p. 74 = *Compsocrinus*, nor p. 75 = *Reteocrinus*.
Not *Glyptocrinus* Etheridge and Nicholson, 1880, Silur. Foss. of Girvan Distr., p. 328.

Syn. *Fossil Encrinite* Anthony, 1838; Amer. Journ. Sci., Vol. XXXV., p. 405.
Syn. *Icosidactylocrinites* Owen, 1843 (Catalogue name).
Syn. *Pycnocrinus* S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 231.

Calyx obconical or subglobose; plates thin, often highly ornamented; the fixed brachials passing imperceptibly into arm plates, and the interbrachials into disk plates; the arms rising vertically from the edge of the tegmen.

Basals five, of uniform size, forming a small cup. Radials and costals of nearly equal size; the second costal hexagonal. Distichals varying in number, there being but two in species in which palmars take part in the calyx; but when the second bifurcation takes place in the free arms, they are quite numerous, frequently six to eight or more in the calyx, followed by several others in the free arms. When this is the case, the second distichal gives off a large pinnule; while in the other the proximal pinnule is developed into an arm. Arms rarely branching beyond the second bifurcation, rising vertically from the calyx; they are long, slender, rounded on the back, and composed of a single series of short, slightly wedge-shaped pieces, which do not interlock. Pinnules slender, closely arranged; the proximal ones the stoutest, and frequently incorporated into the calyx.

Interbrachials definitely arranged; the first large, resting upon the sloping upper faces of the radials; there being two plates in the second row, and two, sometimes three, in the higher ones. The anal side widest, having generally three plates in the second and all succeeding rows. Interdistichal spaces large, composed of numerous small plates; some species also have interpalmars. Ventral disk depressed-hemispherical, very slightly extending above the level of the arm bases; the ambulacra subtegminal, except near the periphery, where some of the small covering pieces are exposed, but the course of the ambulacra is indicated by surface ridges. Plates of the disk very minute and irregularly arranged, decreasing in size toward the arms. The arrangement of the larger plates at the summit is also irregular, being unlike that of orals, which probably are not represented. Anal opening excentric, at the summit of a small protuberance. Column round; axial canal large, pentalobate, the lobes directed interradially, except in one species in which the stem is pentangular and the central canal radially disposed.

*Distribution.* — *Glyptocrinus*, as now amended, is confined to the Trenton and Hudson River groups, and probably is restricted to America.

*Type* of the genus. — *Glyptocrinus decadactylus.*

*Remarks.* — The genus agrees in the uniserial arms and its general structure with *Mariacrinus*, but that has four basals instead of five. It resembles *Compsocrinus*, which has also four basals, but an anal plate in line with the radials, which throws it into the Batocrinidæ.

The European species referred to *Glyptocrinus*, with the possible exception of *G. basilis*, belong to other genera. The specimens described under the name *Glyptocrinus globularis* by Nicholson and Etheridge probably belong to *Archæocrinus*. They evidently had infrabasals, for the interradials rest upon the basals, and they probably had biserial arms.

The following species either are synonyms, undeterminable, or are removed from *Glyptocrinus* to other genera:

| | |
|---|---|
| *Glyptocrinus parvus* HALL, referred to . . . . . . . . . . . | *Ptychocrinus.* |
| " *angularis* MILLER and DYER, synonym of . . . . | *Ptychocrinus parvus.* |
| " *gracilis* WETHERBY, synonym of . . . . . . . | *Ptychocrinus parvus.* |
| " *Harrisi* MILLER, referred to . . . . . . . . . . | *Compsocrinus.* |
| " *Carleyi* HALL, " . . . . . . . . . . | *Mariacrinus.* |
| " *miamiensis* MILLER, " . . . . . . . . . . | *Compsocrinus.* |
| " *Baeri* MEEK, " . . . . . . . . . . | *Xenocrinus.* |
| " *expansus* PHILLIPS, " . . . . . . . . . . | *Sagenocrinus.* |
| " *armosus* MCCHESNEY, " . . . . . . . . . . | *Siphonocrinus.* |
| " *siphonatus* HALL, synonym of . . . . . . . . . | *Siphonocrinus armosus.* |
| " *nobilis* HALL, referred to . . . . . . . . . . | *Siphonocrinus.* |
| " *cognatus* MILLER, synonym of . . . . . . . . . | *Reteocrinus Onealli.* |
| " *O'Nealli* (Nealli) HALL, " . . . . . . . . . | *Reteocrinus.* |
| " *lacunosus* BILLINGS, " . . . . . . . . . | *Archæocrinus.* |
| " *subnodosus* WALCOTT, " . . . . . . . . . | *Rhaphanocrinus.* |
| " *sculptus* MILLER, " . . . . . . . . . | *Rhaphanocrinus.* |
| " *argutus* WALCOTT, " . . . . . . . . . | *Stelidiocrinus.* |
| " *priscus* BILLINGS, " . . . . . . . . . | *Periglyptocrinus.* |
| " *fimbriatus* SHUMARD, undeterminable. | |
| " *libanus* SAFFORD, not defined. | |
| " *plumosus* HALL, detached column and arms. | |
| " *quinquepartitus* BILLINGS, detached column and arms. | |
| " *Pattersoni* MILLER, undeterminable. | |

### Glyptocrinus decadactylus Hall.

*Plate XX. Figs. 4a–e and Plate XXI. Figs. 4a, b.*

1847. Hall; Palæont. N. Y., Vol. I., p. 281, Plate 77, Figs. 1a–f and Plate 78, Figs. 1a–u.
1873. Meek; Palæont. Ohio, Vol. I., p. 30, Plate 2, Figs. 5a, b.
1879. Zittel; Handb. d. Palæont., Vol. I., p. 375, Fig. 262.
1881. W. and Sp.; Revision Palæocr., Part II., p. 188 (Proceed. Acad. Nat. Sci. Phila., p. 362).
1883. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 220, Plate 11, Fig. 1.

Calyx obconical, somewhat higher than wide; the interradial and interdistichal spaces a little flattened, giving a cross-section pentagonal through the costals and decagonal through the distichals. Surface beautifully ornamented with radiating angular ridges; those following the rays to the arms a little the largest and most prominent. Other ridges pass sideways from the centre of the plates, meeting with similar ridges from the interbrachials, which divide the surface into numerous triangular impressed areas.

Basals small, their width at the top greater than the height. Radials heptagonal, larger than the basals, and as wide as long. First costals a little smaller than the radials, and hexagonal; the second as large as the first, but angular above. Distichals two, comparatively large. Arms twenty, simple, rather stout, cylindrical. The four lower plates, which in large specimens are incorporated into the calyx, are elongate, but decrease in length upward; their upper and lower faces being parallel, the succeeding free plates slightly cuneate. Pinnules long, closely arranged; the proximal ones given off from the third palmars, there being none from the distichals. Interbrachials numerous, gradually decreasing in size; arranged in ten to twelve ranges: 1, 2, 2, 2, *etc.*, at the regular sides, sometimes with three plates in the second row. Anal side having three plates in the second and succeeding rows; the plates of the median series longitudinally arranged, and covered by a vertical ridge similar to the ridges along the rays. Interdistichals in four to five rows, the interpalmars in three; the former arranged: 1, 2, 2, 2, 2; the latter placed in a single longitudinal row. Ventral disk slightly convex, composed of irregular pieces with a small prominence in the centre. The plates are small, and gradually decrease in size outward, those along the margin being quite minute, and enclose some of the "*Saumplättchen*." The latter, which are also frequently preserved upon the arms and pinnules, consist of two very small irregular rows of pieces. Anus subcentral, at the upper end of a protuberance. Column round, of moderate size, the nodal joints a little the widest; axial canal rather large and pentalobate.

*Horizon and Locality.* — Hudson River group; Cincinnati, O.; Waynesville, O., and Maysville, Ky.

*Remarks.* — It has been supposed by several writers that *G. decadactylus* had rudimentary infrabasals, but this is not the case. In a fine specimen from which every vestige of the stem was removed, we could follow the interbasal sutures to the axial canal, and found the latter to be interradial and not radial, the part which had been supposed to represent the infrabasals being the upper stem joint.

### **Glyptocrinus Dyeri** MEEK.

*Plate XX. Figs. 1a, b, c; and Plate XXI. Figs. 3a, b, c, and Fig. 6.*

1872. MEEK; Proceed. Acad. Nat. Sci. Phila., p. 314.
1873. MEEK; Geol. Rep. Ohio, Palæont., Vol. I., p. 32, Plate 2, Figs. *2a, b* (not *2c*).
1881. W. and SP.; Revision Palæocr.; Part II., p. 188.
1883. S. A. MILLER; Journ. Cincin. Soc. Nat. Hist., p. 222.

Syn. *Glyptocrinus Dyeri* var. *subglobosus* — MEEK; 1872, Proceed. Acad. Nat. Sci. Phila., p. 340; also Geol. Rep. Ohio, Palæont., Vol. I., p. 34, Plate 2, Fig. *2c*.

Syn. *Glyptocrinus subglobosus* — W. and SP.; 1881, Revision Palæocr., Part II., p. 189.

Syn. *Glyptocrinus Richardsoni* — WETHERBY; 1880, Journ. Cincin. Soc. Nat. Hist., Vol. II., p. 245, Plate 16, Figs. 1 and *1a*.

Syn. *Reteocrinus Richardsoni* — W. and SP.; Revision Palæocr., Part II., p. 193.

Of the type of *Glyptocrinus decadactylus*, but the calyx globose instead of obconical. It has a similar ornamentation, but the ridges are less angular, being rounded, and those following the radial and anal plates are more prominent; the arms are thinner, and the second bifurcation takes place in the arms.

Basals small, much wider than long, with a sharp, almost circular rim around the bottom, which extends slightly beyond the column. Radials and costals a little wider than long, the latter somewhat the smallest. Distichals nine to sixteen or more, their number varying among the rays, the five to eight lower ones forming part of the calyx, the others being arm plates. The two lower distichals nearly as large as the upper costals. The succeeding plates decrease rapidly in size upwards. Their second plate has the form of an axillary, giving off to the outer side of the ray a large pinnule; the third is quadrangular and bears no pinnule; the fourth plate bears the second pinnule at the inner side of the ray, above which every plate is pinnule-bearing. In large specimens, as much as six pinnules are incorporated into the calyx, and these are not only larger than the succeeding ones, but are placed farther apart. The apposed faces of the distichals, and apparently of all arm plates, are covered with well marked radiating striæ and grooves. The arms in their free state branch but once; they are rather thin, especially at the upper ends, and composed of short, somewhat cuneate pieces. Interradial spaces slightly impressed between the costals, and distinctly grooved between the distichals. First interbrachials about as large as the radials; the plates of the second row a little smaller, supporting a fourth plate between their upper sloping faces, and two plates in the next two rows, followed by numerous small pieces, which enclose the fixed pinnules. The anal area is a little wider, having three plates in the second and all succeeding rows up to the first pinnule; the middle series being marked by a rather conspicuous ridge. Interdistichal spaces elongate, their median portions deeply grooved; the first plate large, followed by two plates in the second row, and a number of small pieces above. Construction of the ventral disk, and position of the anus unknown. Column round, — not indistinctly pentangular as stated by Meek; the nodal joints somewhat larger; the axial canal pentalobate, and moderately large.

*Horizon and Locality.* — Hudson River group; at Cincinnati, Lebanon and Waynesville, Ohio, and also found at Richmond, Ind.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — This species is readily distinguished from *G. decadactylus*, its nearest ally, by the uninterrupted series of anal plates. It is quite remarkable for its large number of incorporated pinnules, of which the proximal ones have almost the proportions of armlets. Meek's *G. Dyeri*, var. *globosus*, which we thought to be a good species, judging from the figures, can hardly rank even as a variety. We have examined the type in the Museum of Comparative Zoölogy, and find it to have all the characteristics of *G. Dyeri*. Wetherby's *G. Richardsoni* also, which we once regarded as a *Reteocrinus*, is based upon a somewhat aberrant specimen of this species.

### (?) **Glyptocrinus Shafferi** MILLER.

*Plate XXI. Figs. 3d, e, f.*

1875. *Glyptocrinus Shafferi* — S. A. MILLER; Cincin. Quarterly Journ. Sci., Vol. II., p. 277; and 1880, Journ. Cincin. Soc. Nat. Hist., Vol. III., p. 233, Plate 7, Figs. 2*a*, *b*, and 3*a*, *b*, *c*.
1881. *Glyptocrinus Shafferi* — W. and SP.; Revision Palæocr., Part II., p. 189.
1883. *Pycnocrinus Shafferi* — S. A. MILLER; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 231, and North Amer. Geol. and Palæont., p. 276.

There is but little doubt that the small specimens which S. A. Miller described as *Glyptocrinus Shafferi*, and *G. Shafferi*, var. *germanus*, and for which he afterwards proposed the genus *Pycnocrinus*, are young examples of *Glyptocrinus Dyeri.* The specimens have variously from nine to twelve distichals, but in place of having six to eight of them incorporated into the calyx, only one or two are calyx plates, the others being free. That the specimens are comparatively smaller, the column stouter, the basals proportionately larger, the interbrachials and interdistichals less numerous, the arm joints higher, the pinnules stronger and placed farther apart, all indicate a less mature stage of individual growth, a phase through which every *Glyptocrinus* must naturally have passed.

Miller defines *Pycnocrinus* as follows: "Calyx cup-shaped. Column round. Basals five, small, pentagonal. Primary radials $3 \times 5$. Secondary radials none. Regular interradials three. Arms ten, but sometimes dividing after becoming free. Pinnules dense and strong." This description would apply equally well to any young *Glyptocrinus*. It must be remarked, however, that both of Miller's types have small interdistichals, which he overlooked. The presence of these plates proves conclusively that at least one of the distichals takes part in the calyx, and that "secondary radials" are not unrepresented in those specimens, as Miller supposed.

*Horizon and Locality.* — Found associated with the two preceding species at Cincinnati and other places.

*Type* in the collection of S. A. Miller.

### **Glyptocrinus ramulosus** Billings.

*Plate XX. Figs. 5a, b.*

1856. E. Billings; Canadian Naturalist and Geologist, No. 1, p. 54; also Geol. Surv. of Canada (Rep. of Progress), 1857, p. 258, and 1859, Decade IV., p. 57, Plate 7, Fig. 2*a* and Plate 8, Fig. 1.
1881. W. and Sp.; Revision Palæocr., Part II., p. 189.
1883. S. A. Miller; Journ. Cincin. Soc., Nat. Hist., p. 224.

A large species. Dorsal cup obconical, somewhat rounded at the base. Costals and distichals remarkably uniform in size; also the palmars proportionally large. Plates almost flat and without any markings, except a conspicuous, obtusely angular ridge passing up the rays, occupying nearly one half their width.

Basals small, only the upper angles visible from a side view. Radials somewhat larger than the costals, as long as wide. Distichals six, exceptionally seven; the proximal one as long as the costals, but a little narrower; the succeeding ones smaller. There are fixed pinnules from the second, fourth and fifth plates (none from the third), which are long, but not as conspicuous as in the preceding species, and they grow more obscure with age. All brachials of the third order are free; the two or three lower ones are longer and have parallel upper and lower faces; the others being short and cuneiform. The arms, which branch once, are long, very slender, rounded on the back, and provided with rather long pinnules. Interbrachial plates large, to the fifth row nearly of equal size, and as large as the second distichals; arranged: 1, 2, 2, 2, 2. From the sixth row, where the pinnules come in contact with the interbrachials, the arrangement is less regular, and the plates gradually grow smaller. There seems to be no anal ridge, but the posterior interradius has three plates in the third row, and frequently in the second. The interdistichal spaces are remarkable for their great length, and the large size of the plates; they are arranged: 1, 1, 2, 2, 3. Construction of ventral disk, and position of anal opening unknown. Column round, composed of short, sharply edged joints.

*Horizon and Locality.* — Trenton limestone; Ottawa, Canada.

*Types* in the Canada Survey Museum.

### Glyptocrinus ornatus Billings.

*Plate XX. Figs. 6a, b.*

1857. Billings; Geol. Surv. of Canada (Rep. of Progress), p. 260; also 1859, ibid., Decade IV., p. 60, Plate 9, Figs. 2*a*, *b*.
1881. W. and Sp.; Revision Palæocr., Part II., p. 189.
1883. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 225.

Of the type of *Glyptocrinus Dyeri*, but readily distinguished by its ornamentation, the smaller number of interbrachial and anal plates, and by having ten arms instead of twenty. Calyx globose, the plates delicate, ornamented with five or six rather conspicuous, finely striated ridges, radiating from the centre of the plates. The ridges passing up the radial and anal plates are more prominent and broader than the others; those from the interbrachials, which are not confluent with the ridges of adjoining plates, forming a well defined star upon each plate.

Base short, with a projecting rim and a shallow depression at the bottom. Radials and costals a little wider than long, the radials one third the largest. Four of the distichals generally take part in the calyx, of which the two proximal ones are nearly as large as the upper costal, the second pinnule-bearing; the two succeeding ones are much smaller, but yet twice as large as the free brachials. Arms ten, slender, not bifurcating; composed of quadrangular, moderately high joints with long pinnules. Interbrachials: 1, 2, 2, 2, decreasing in size upwards. The anal interradius considerably wider: 1, 3, 3, *etc.*; the middle series longitudinally arranged, and marked by a conspicuous ridge. Interdistichals: 1, 2, *etc.* Construction of ventral disk and anus unknown. Column obscurely pentagonal to judge from the top joint; the axial canal of medium size.*

*Horizon and Locality.* — Trenton limestone; Ottawa, Canada.

*Types* in the Canada Survey Museum at Ottawa.

### **Glyptocrinus marginatus** Billings.

*Plate XX. Fig. 2.*

1856. *Glyptocrinus marginatus* — E. Billings; Geol. Surv. Canada (Rep. of Progress), p. 260; also 1859, Decade IV., p. 59, Plate 9, Fig. 1*a*.
1881. *Archæocrinus marginatus* — W. and Sp.; Revision Palæocr., Part II., p. 190.
1859. *Archæocrinus marginatus* — S. A. Miller; N. Amer. Geol. and Palæont., p. 225.

A large and well marked species. Exact form of calyx undeterminable — the only specimen being in a crushed condition — but probably subglobose. Plates evenly margined by a strong elevated border crossing the radial ridges, their middle portions smooth and very thin; the inner floor of the plates marked by slender conspicuous tubercles. Radial ridges not very prominent, wide and flattened.

Basals small, projecting laterally. Radials and costals as long or a little longer than wide; the former twice as large as the costals. Distichals about seven; all, or nearly all, incorporated into the calyx, rapidly decreasing in size; the proximal one as large as the costals, and of similar form; the upper axillary, and succeeded by free arm plates. Arms delicate, composed near the calyx of moderately long (nearly as long as wide), slightly cuneate joints. There are apparently no fixed pinnules; the free pinnules long, stout at the base, distinctly tapering. Interbrachials: 1, 2, 2, 1, 2, 3, 2, followed by others; their five lower ones of nearly the same size as the radials. Anal area considerably wider, and composed of a much greater number of plates than in any other species of the genus. It contains a middle series of anal plates, marked by an obscure ridge, and to both sides of this ridge there are numerous interbrachials, arranged like those of the four regular sides, but

* It is doubtful if the detached column, which Billings found associated with the type specimen, belongs to this species.

the plates somewhat smaller. Nothing is known of the ventral disk, the anal opening, and the upper portions of the arms. Column strong, round; composed of alternate thick and thin joints, all rounded along the edges, the former twice as high as the latter, and somewhat wider. Axial canal large, pentalobate.

*Horizon and Locality.* — Trenton limestone; City of Ottawa, Canada.

*Remarks.* — This species has a superficial resemblance to certain species of *Archæocrinus*, and in 1881 we referred it to that genus. But on examining the type specimen from the Canada Survey Museum we find it has no infrabasals, and the angles of the axial canal are interradially disposed.

### (?) **Glyptocrinus Fornshelli** S. A. Miller.

*Plate XX. Fig. 3, and Plate XXI. Fig. 5.*

1874. S. A. Miller; Cincin. Quart. Journ. Sci., p. 348.
1881. W. and Sp.; Revision Palæocr., Part II., p. 188.
1883. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. VI., p. 227; and North Amer. Geol. and Palæont., p. 248.

Calyx elongate, obconical; dorsal cup almost twice as high as wide, its sides convex. Plates delicate and beautifully ornamented, being traversed by sets of from five to seven small ridges, a set directed to each side of the plate, and each set continued upon adjoining plates. The ridges of the same set are parallel, those of different sets meeting at an angle at the middle of the plates, and being so arranged as to form numerous rhombs, each containing two sets of included triangles. Upon the radials and costals the median ridge is but slightly stronger than the others, but on approaching the distichals it enlarges rapidly, and at the fifth plate it attains the proportions of an arm.

Basals small, forming a short cup; the interbasal sutures deeply notched. Radials and costals longer than wide, their upper and lower faces unusually narrow; the first costal somewhat longer than the radials, the second a little smaller generally. Of the distichals, the ten to twelve lower plates take part in the calyx; the three proximal ones being but third smaller than the costals; the fourth is considerably shorter, and the succeeding ones almost as short as the free brachials. Arms bifurcating (once or oftener), long, very slender at their tips; constructed of moderately short, cuneate pieces with stout and long pinnules. Interradial and interdistichal areas elongate, and composed of an unusually large number of pieces; the former arranged in one of the specimens: 1, 2, 3, 3, 3, 3, 3, 3, 4, 4; the latter: 1, 2, 3, 3, 3, *etc*. The anal side contains three plates in the second row, and there are other extra plates above. Nothing is known of the ventral disk or anal opening. Column sharply pentangular; the nodal joints the longest, their edges flattened (not convex); internodal joints short and angular in the upper part of the stem, but gradually growing as large as the nodal ones; axial canal wide and slightly pentalobate, the lobes disposed *radially*, in the same direction as the outer angles of the stem.

*Horizon and Locality.* — Upper part of the Hudson River group; at Morrow and Waynesville, O.

*Types* in the collection of Mr. F. L. Fornshell.

*Remarks.* — It is with some hesitation that we place this species under *Glyptocrinus*. It differs from all other species of the genus in the pentangular stem, and the radial position of its axial canal, a feature in which it is at variance with all other known monocyclic Palæocrinoids. That it actually has no infrabasals, we ascertained from a fragmentary specimen by exposing the inner floor of the basal cup. It has in the centre a large pentangular open space, whose angles are pointed to the interbasal sutures, taking the same direction as the angles of the stem. A somewhat similar departure from the rule is claimed to exist in the recent genus *Pentacrinus*, in which, however, stem and canal are *inter*radial.

### PERIGLYPTOCRINUS W. and Sp. (nov. gen.).

Closely allied to *Glyptocrinus*, but having larger basals and well developed *biserial* arms; the arms of *Glyptocrinus* being described by all writers as uniserial. The only two species known to us are our new species *Periglyptocrinus Billingsi*, which we make the type of that genus, and *P. priscus*, which was described by E. Billings as a *Glyptocrinus*. Fragments of a third species are found in Alexander County, Ills.

*Distribution.* — Black River shale, and Trenton limestone of Canada.

### Periglyptocrinus Billingsi W. and Sp. (nov. sp.).

*Plate XXI. Figs. 1a, b.*

A beautiful and highly ornamented species. Dorsal cup elongate-obconical, higher than wide, somewhat depressed at the interradial and interdistichal spaces. The plates marked by rounded ridges, one to each side of the plates; those upon the radials and fixed brachials much wider and more prominent. The ridges tapering to the margins of the plates, so as to form bead-like elevations along the rays, and a well defined star upon each interbrachial.

Basals large, forming an elongate cup, which is deeply grooved at the interbasal sutures, and the sides of the plates are bordered by conspicuous ridges, which are prolonged to the upper part of the radials. Radials and costals large, longer than wide; the radials larger than the costals. Distichals two. Palmars free from the fourth plate. Arms twenty, simple, long, slender, gradually tapering to their tips, and beyond the fourth or fifth plate strictly biserial. The first pinnule is given off from the second palmars, and all succeeding brachials are pinnule-bearing. Interbrachials: 1, 2, 2, 2, 2, *etc.;* the lower one considerably the larger. Interdistichals: 1, 1, 1; interpalmars: 2 to 3. Anal interradius the widest, the lower plates somewhat larger than the corresponding plate of the four other sides. It contains three plates in the second and all succeeding rows, the middle series marked by a somewhat interrupted longitudinal ridge. Similar but shorter ridges proceed from the first anal plate to adjacent radials. Construction of ventral disk, and position of anus not known. Column slightly decreasing in size downward; round; composed of rather long joints with convex edges; the nodal joints considerably thickest. At three inches from the calyx, each internode contains seven to eight joints, of which every second or third is nearly as large as the nodal ones.

*Horizon and Locality.* — Trenton limestone, Ottawa, Canada.

*Types* in the Canada Survey Museum at Ottawa; collected by Mr. John Stewart.

We take pleasure in dedicating this elegant species, the type of a new genus, to our friend Mr. Walter R. Billings, the author of several important papers on Crinoids, to whom we are indebted for many favors.

V

### **Periglyptocrinus priscus** (Billings).

*Plate XXI. Fig. 2.*

1856. *Glyptocrinus priscus* — E. Billings; Geol. Surv. Canada (Rep. of Progress), p. 287; also 1859, Decade IV. p. 56, Plate 7, Figs. 1*a*, *b*, *c*.
1881. *Glyptocrinus priscus* — W. and Sp.; Revision Palæocr., Part II., p. 189.
1883. *Glyptocrinus priscus* — S. A. Miller; Journ. Cincin. Soc. Nat. Hist., p. 225.
1883. (?) *Archæocrinus priscus* — W. and Sp.; Revision Palæocr., Part III., p. 301.

A small species. Dorsal cup obconical with slightly convex sides; section across the costals sharply pentagonal, owing to the conspicuous radial ridges, which pass from the arms down to the centre of the radials, where they divide and are continued to the basals. The ridges, which are rounded, grow narrower toward the middle of the plates, widening at their margins. Surface, except along the ridges, covered with numerous small pustules without definite arrangement.

Basals large, forming a pentagonal cup with a rim around the bottom. Radials twice or nearly three times as large as the second costals; the first costal larger than the second. Distichals free beyond the fourth plate; the first and second considerably the larger; the second one pinnule-bearing, and also the fourth (not the third), which is slightly wedge-shaped, and considerably smaller than the preceding ones; from the fifth to the eighth, the plates are decidedly cuneate, the higher ones interlocking. Arms 10, simple throughout; thin, composed of two series of trigonal pieces. Interbrachials: 1, 2, 2, *etc.;* the plates large. Anal side slightly wider; the first plate a little larger than the corresponding ones of the other sides; the succeeding pieces comparatively smaller; there are three plates in the second row, and in all the rows above. The plates of the median series are formed into a conspicuous longitudinal ridge, which divides on the first anal plate, sending a branch to the middle of adjacent radials. Nothing is known of the structure of the ventral disk and anal opening, and nothing definitely of the column.

*Horizon and Locality.* — Black River limestone; Renfrew Co., Canada.

*Type* in the Canada Survey Museum at Ottawa.

*Remarks.* — The large columns which E. Billings figures from the Trenton group of Ottawa, and which he thought might be referable to *G. priscus*, probably belong to a different species.

## STELIDIOCRINUS Angelin (Restricted by W. and Sp.).

1878. Angelin; Iconogr. Crinoid. Suec., p. 21.
1879. Zittel; Handb. der Palæont., Vol. I., p. 345.
1881. W. and Sp.; Revision Palæocr., Part II., p. 98 (Proceed. Acad. Nat. Sci. Phila., p. 272).
1885. W. and Sp.; ibid., Part III., p. 102 (Proceed. p. 324).

Calyx small, subturbinate, plates smooth; interradial areas depressed; radial plates elevated but not ridged; ventral disk composed of but few plates.

Basals five, forming an acute-angled pentagon. Radials large, wider than long; lunate. Costals two; the first quadrangular; the second much larger, almost as large as the radials. Distichals $2 \times 10$ in the calyx, the others free arm plates. Arms ten, simple, uniserial, rather stout; pinnules strong. Interbrachials: 1, 2, 1; the first very large, rising to the top of the first costals. Anal area wider, containing three plates in the second and third rows, and smaller ones above. Anus excentric, represented by a simple opening, which faces laterally. Ventral disk low, the orals very large, occupying in *S. capitulum* fully three fourths of the whole surface. Column round.

*Distribution.* — Hitherto found only in the Upper Silurian of Gotland, Sweden, but we now refer to this genus Walcott's *Glyptocrinus argutus* from the Trenton limestone of New York, with some doubt.

*Remarks.* — Angelin's descriptions and figures are so confusing that no uniform generic characters can be deduced therefrom, unless some are eliminated. Taking the first species *S. capitulum*, Iconogr. Plate XVII., Figs. 5–5*g*, and the first figures of his second species *S. laevis*, ibid., Plate XV., Fig. 20, we have the type indicated by the above descriptions; but Plate XXVIII., Figs. 7*a*, *b*, figured also as *S. laevis*, is clearly a *Desmidocrinus*, and the specimen represented on Plate XXXII., Figs. 3 and 3*a*, is probably incorrectly figured, either as to the anal side or the arms. Plate XIX., Fig. 6, figured as *S. ovalis*, is a totally different thing, and probably belongs to the Rhodocrinidæ. Plate XXI., Figs. 6, 7, described by Angelin as *Harmocrinus*, and considered by us (Revision, II., p. 99) as belonging to *Stelidiocrinus*, has very possibly a dicyclic base, and strongly resembles *Thysanocrinus*. We have not the material to settle these questions, but by restricting the genus to the above mentioned forms, we have something tangible. The genus, as thus defined, differs widely from any other of this group, especially in the structure of the disk, which is quite remarkable. The quadrangular first costal distinguishes it from the associated genera with five basals.

### (?) **Stelidiocrinus argutus** (Walcott).

*Plate XXIV. Fig. 6.*

1883. *Glyptocrinus argutus* — Walcott; 35th Rep. N. Y. State Mus. Nat. Hist., Plate 17, Fig. 9.
1885. (?) *Stelidiocrinus argutus* — W. and Sp.; Revision Palæocr., Part II., p. 102.

Calyx small, somewhat pentangular; the interradial spaces depressed. Basals five, rather large. Radials subquadrangular, the upper faces moderately concave; their upper corners but slightly truncated. First costals quadrangular, not more than half the size of the radials, a little wider than long, the lower face convex. Second costals nearly as large as the radials, their upper faces forming an obtuse angle. Distichals one in the calyx. Arms two to the ray; composed of rather stout quadrangular pieces. The two or three proximal free plates about as long as wide, the others comparatively longer, and increasing in length upward. The pinnules, which are very stout, almost take the form of armlets; they are placed far apart, and their joints, like those of the arms, grow longer upwards. Interbrachials three preserved in the specimen, but having others above; the arrangement of the plates at the anal side unknown. Column of medium size; the joints rounded at their edges, and decreasing in height downward.

*Horizon and Locality.* — Upper part of Trenton limestone; Trenton Falls, N. Y.

*Type* in the Museum of Comparative Zoölogy, Cambridge.

*Remarks.* — We refer this species with some doubt to *Stelidiocrinus*, which it approaches in its general characters; but as nothing is known of the structure of its anal side, it may belong to a different genus, and perhaps to the Dolatocrinites.

### MARIACRINUS HALL (emended W. and SP.).

1859. HALL (in part); Palæont. N. Y., Vol. III., p. 104.
1881. W. and SP.; Revision Palæocr., Part II., p. 114 (Proceed. Acad. Nat. Sci., Phila., p. 288).
1885. W. and SP.; Revision Palæocr., Part III., p. 104 (Proceed. Acad. Nat. Sci., Phila., p. 326).
1889. S. A. MILLER; N. Amer. Geol. and Palæont., p. 259.

Calyx obconical, in general aspect resembling *Glyptocrinus;* interradial and interdistichal spaces large and more or less depressed; the posterior interradius distinguished by having three plates in the second row; the plates of the rays marked by a strong longitudinal ridge.

Basals four, small, almost of uniform size. The one facing the anterior side a little the largest and pentangular, the others irregularly quadrangular. Radials and costals of similar size; costals two, the first hexagonal. Distichals two to four. The palmars, of which generally the proximal plate only takes part in the calyx, support the arms. Arms composed of cuneiform pieces, which either remain simple, or give off a few branches to one side. Pinnules given off from opposite sides. Interbrachials rather numerous; anal side a little wider, and containing additional plates. Ventral disk flat; composed, so far as observed, of very minute, irregular pieces, apparently without oral plates. Anus excentric, opening out directly through the tegmen. Column round; axial canal of medium size, and obtusely pentangular.

*Distribution.* — Upper Silurian of America, England, and Sweden.

*Remarks.* — Hall in proposing this genus made "*Mariacrinus*" *nobilissimus* the type of a genus, which in all essential characters agrees with *Melocrinus* Goldf., notably in the arm structure; the arms being given off from the sides of tubular appendages. Among the species referred by Hall to *Mariacrinus* were some with a very different arm structure, and in 1881 we reconstructed the genus with *Mariacrinus plumosus* and *M. Carleyi* as types. The genus, as we proposed it, includes only those species with four basals in which the arms are given off directly from the calyx.

Zittel regards *Mariacrinus*, as typified by *M. nobilissimus*, as a synonym of *Ctenocrinus* Bronn, in which we agree; but the latter genus, according to Schultze,* is identical with *Melocrinus*.

*Mariacrinus macropetalus* Hall is probably a *Corymbocrinus* Angelin; *Mariacrinus stoloniferus* Hall is described from fragmentary columns. *Glyptocrinus Harrisi* S. A. Miller, which we erroneously referred to *Mariacrinus*, not knowing it had an anal plate between the radials, has been transferred to *Compsocrinus*. *Mariacrinus granulosus* S. A. Miller is too fragmentary for identification, but certainly belongs to a very different group.

### **Mariacrinus Carleyi** (Hall).

*Plate XXII. Figs. 2a, b, c.*

1863. *Glyptocrinus Carleyi* — Hall; Trans. Albany Inst., Vol. IV., p. 203; also 28th Rep. N. Y. State Mus. Nat. Hist., 1875, p. 132, Plate 14, Figs. 7-10.
1881. *Glyptocrinus Carleyi* — Hall; 11th Ann. Geol. Rep. Indiana, p. 261, Plate 13, Figs. 7 to 11, and Plate 15, Fig. 5.
1881. *Mariacrinus Carleyi* — W. and Sp.; Revision Palæocr. Part II., p. 116.

Calyx obconical, higher than wide; the sides distinctly convex, section across the costals sharply pentagonal, and across the distichals decagonal; the radials marked by very prominent rounded ridges; the interradial spaces depressed. Narrower and more angular ridges pass out to the sides of the radials, where they meet with others from the interbrachials, dividing the surface of the dorsal cup into numerous triangular depressed areas, which

* Monogr. Echinod. Eifler Kalk., p. 61.

are thickly covered with fine granules, producing a most beautiful ornamentation.

Basals small, forming a short cup; the columnar attachment small; the axial canal pentalobate. Radials and costals large, as wide as long. Distichals two or 3 × 10, somewhat smaller. Palmars three to four in the calyx, decreasing in length upwards; the upper plates of the two inner divisions axillary, supporting two arms, those of the outer divisions quadrangular, bearing a single arm from the calyx. Arm openings thirty, directed upwards and not visible from a side view; the arms are not preserved in any of the specimens. Interbrachials: 1, 2, 3, 3, 3; followed by other minute pieces, which pass into the disk. Anal side wider: 1, 3, 4, 4, *etc.;* the first plate larger than the corresponding plate of the other sides, and there being no anal ridge. Ventral disk very short, almost flat; the interambulacral spaces depressed. Surface covered by hundreds of very minute pieces without orals, the plates being so small as to be readily taken for mere granules. Anus excentric, placed at the summit of a small protuberance. Column unknown.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

### Mariacrinus Warreni Ringueberg.

*Plate XXII. Fig. 1.*

1888. Ringueberg; Proceed. Acad. Nat. Sci. Phila., p. 133, Plate 7, Fig. 4.

Of the type of M. Carleyi, but having two distichals instead of three, and no palmars in the calyx. It also differs from that species in the details of its ornamentation. Calyx obconical, slightly contracted above the second costals. Radial ridges rounded, wide and quite prominent; the surface finely corrugated; and there are series of smaller transverse ridges meeting those from the interbrachials.

Basals four, forming a conical cup. Radials and costals comparatively large, wider than high. Distichals two, rather small. Palmars two or three in the calyx; in form resembling arm plates, but longer. Arms twenty; long, slender, tapering gradually to a sharp point; the joints short, quadrangular; their upper and lower faces almost parallel. Pinnules delicate, long, closely packed; composed of joints twice as long as wide. The arrangement of the interbrachials cannot be accurately ascertained from the specimen, but it is apparent that the proximal plate at all sides rests upon the sloping upper faces of two radials. Neither is anything known of the construction of the disk. Column round, of moderate size, slightly tapering downwards; near the calyx the nodal joints are somewhat larger than the internodal ones, but at a length of about three inches all joints are of nearly equal size.

*Horizon and Locality.* — Niagara shale; Lockport, N. Y.

*Type* in the collection of Dr. Eugene Ringueberg, Lockport.

**Mariacrinus plumosus*** Hall.

*Plate XXIII. Figs. 6 and 7.*

1859. Hall; Palæont. New York, Vol. III., p. 110, Plate 3, Figs. 6-11.
1881. W. and Sp.; Revision Palæocr. Part II., p. 116.

A small species. Dorsal cup apparently obconical; the surface ornamented by strong radiating ridges, proceeding from the centre of the plates to adjoining ones. Basals about as long as wide. Radials a little longer than wide. Costals nearly as large as the radials and of similar form. Distichals 3 × 10, each row supporting two arms, twenty in all. Arms simple, rather long. composed of slightly cuneate joints. In the two outer arms, the second joint gives off a pinnule to the outer side, the third is a hypozygal joint, and the fourth gives off the second pinnule at the inner side; all succeeding joints being pinnule-bearing. The two inner arms, according to Hall, support no pinnules up to the eighth joint, but this needs confirmation. Interbrachials, 1, 2, 2, 2. The arrangement of plates in the anal interradius and construction of the ventral disk unknown. Column round, comparatively large.

*Horizon and Locality.* — In the shaly layers of the Pentamerous limestone, Wheelock's Hill, Litchfield, Herkimer Co., N. Y.

(?) **Mariacrinus ramosus*** Hall.

1859. Hall; Palæont. New York, Vol. III., p. 147, Plate 2, Fig. 6.
1881. W. and Sp.; Revision Palæocr., Part II., p. 116.

Dorsal cup urn-shaped, the rays marked by strong ridges, which pass into the arms. Basals small. Radials and costals higher than wide. Distichals

* We are somewhat in doubt as to the generic relations of this species, and think it possible from Hall's figure that it may possess infrabasals, and therefore belong to a different genus. We do not reproduce the original figure, because it does not agree with the description, either in the arrangement of the plates in the calyx, or the construction of the arms. We had no opportunity to see the type specimen, and only can give an abstract of Hall's description.

3 × 10, each series supporting two arms, or twenty from the calyx. The two inner arms branch three times, the outer ones remain simple. Above the last bifurcation, according to Hall, the arms are composed of a "double series of wedge-formed plates, and below these points of a simple series of quadrangular plates," with rounded pinnules.

*Horizon and Locality.* — Same as last.

### Mariacrinus aureatus S. A. Miller.

(After Miller.)

1891. Adv. Sheets 17th Rep. Geol. Surv. of Indiana, p. 34, Plate 6, Fig. 36.

Calyx very small. Dorsal cup bowl-shaped; plates covered with angular ridges passing out from their centres. Basals four, unequal; exposed beyond the column. Radials the largest plates of the calyx, wider than high. First costals a little smaller, their width greater than the length; pentangular or hexangular. Second costals as long as wide. Distichals two in the three anterior rays, three in the posterior ones; the second plate of the former axillary. Interradial areas elongate, subovate. Regular sides composed of seven or eight plates: 1, 2, 2, 2; the first nearly as large as the radials. Interdistichals one or two. The anal side has nine or ten plates, there being three in the second, and four in the third row; the plates of the upper row very small. Arm structure and tegmen not preserved in the specimens.

*Horizon and Locality.* — Niagara group; St. Paul, Ind.

## MACROSTYLOCRINUS Hall.

1852. Hall; Palæont. N. York, Vol. II., p. 203.
1857. Pictet; Traité de Paléontologie, Vol. IV., p. 329.
1862. Dujardin and Hupé; Hist. natur. des Zooph. Echin., p. 149.
1863. Hall; Trans. Alb. Inst., Vol. IV., p. 207 (Abstr. p. 12).
1879. Hall; Mus. edit. 28th Rep. N. Y. State Mus. Nat. Hist., p. 128.
1879. Zittel; Handb. d. Palæont., Vol. I., p. 368.
1881. W. and Sp.; Revision Palæocr., Part II., p. 102; also Proceed. Acad. Nat. Sci. Phila., p. 276.
1881. Hall; 11th Ann. Rep. Geol. of Ohio, p. 256.
1882. Ringueberg; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 119.
1882. de Loriol; Paléont. Française, Tome XI., Crinoïdes, p. 56.
1883. W. and Sp.; Revision Palæocr., Part III., p. 102; also Proceed. Acad. Nat. Sci. Phila., p. 324.
Syn. *Actinocrinus* (in part) — Lyon; Proceed. Acad. Nat. Sci. Phila., 1861, p. 411.
Syn. *Cyathocrinus* (in part) — Hall; Doc. edit., 28th Vol., N. Y. State Mus. Nat. Hist. (Explanation of Plate 13).
Syn. *Ctenocrinus* (in part) — Shumard; Trans. Acad. Sci. St. Louis, Vol. II., p. 360.

Specimens small. Calyx obconical to subglobose; generally with prominent ridges along the radial and anal plates; the surface densely covered with very fine striæ or small granules.

Basals three, large, unequal, forming a more or less deep cup; two of the plates equal, the other one half smaller. Radials very large; their upper corners but slightly truncated by the interbrachials. Costals two, small; rarely more than one third the size of the radials, and in some species still smaller. Of the distichals generally only the first plate takes part in the calyx, but occasionally also the second. Arms ten, long, biserial, and simple throughout. Interbrachials few. Anal area much the widest and quite distinct. It has three plates in the first row, of which the middle one is placed against the sloping upper faces of the two posterior radials; while the two smaller ones at the sides, together with the first costal, occupy the upper face of the plate, in a similar manner as the corresponding plates of the Platycrinidæ, except that those of *Macrostylocrinus* do not extend beyond the limits of the dorsal cup. The middle or anal plate is generally followed by one or two other anals, longitudinally arranged. Ventral disk low; composed, so far as observed, of small irregular pieces. Column round; axial canal small.

*Distribution.* — Restricted to the Niagara group of America.

*Type* of the genus: *Macrostylocrinus ornatus* Hall.

*Remarks.* — This genus differs from all other Melocrinites in the number of basals, and in having in the anal interradius three plates in the first row, while the others have but one. The anal side of Hall's diagram on page 130 of the 28th Rep. N. Y. State Museum is incorrectly given, and it appears from the description that Hall was not aware that in *Macrostylocrinus* the arrangement of plates in the anal interradius differs from that of the other sides. The basals in that diagram are represented as equal, while in fact they are unequal, two of them being larger than the third.

Shumard regarded this genus as identical with *Ctenocrinus* Bronn, from which it differs in the construction of the anal interradius — the latter having but one plate in the first row — and also in the number of basals.

### **Macrostylocrinus ornatus** HALL.

*Plate XXIII. Figs. 8a, b, c.*

1851. *Macrostylocrinus ornatus* — HALL; Palæont. N. Y., Vol. II., p. 204, Plate 46, Figs. 4*a–g*.
1866. *Ctenocrinus ornatus* — SHUMARD; Trans. Acad. Sci. St. Louis, p. 361.
1881. *Macrostylocrinus ornatus* — W. and SP.; Revision Palæocr., Part II., p. 103.

Dorsal cup about as high as wide; cross-section subpentangular; the median portions of the basals and costals slightly elevated; their surfaces, and those of the radials, covered with fine, interrupted striæ, and the interbrachials with elongate tubercles, which at the centre of the plates become obsolete. The suture lines well defined.

Basals not as large as in some of the other species, forming a shallow basin with obtuse upper angles. Radials more than twice as large as the costals, slightly spreading; the upper faces somewhat shorter than the lower First costals hexagonal, their upper sloping faces much shorter than the sloping lower ones; the second costals smaller than the first, the upper side obtusely angular. Distichals free above the first; the three proximal plates quadrangular, the edges of their upper and lower faces crenulated; the succeeding three or four plates cuneate, and the plates above interlocking so as to form two rows of arm plates; the latter covered by two rounded tubercles, transversely arranged, and placed in rows longitudinally. Arms ten, long and rounded. Regular interbrachials three known; the lower plate twice as large as the two upper; the latter resting against the sides of the second costals, slightly touching the first. All other parts of the species unknown.

*Horizon and Locality.* — Shales of the Niagara group; Lockport, N. Y.

*Remarks.* — We have been unable to trace the type specimen, and our description was made from Hall's figure in the New York Report.

### **Macrostylocrinus striatus** Hall.

*Plate XXII. Figs. 14a, b, c.*

1863. Hall; Trans. Alb. Inst., Vol. IV., p. 207 (abstr. p. 13).
1866. Shumard; Trans. Acad. Sci. St. Louis, Vol. II., p. 361 (*Ctenocrinus striatus*).
1879. Hall; 28th Rep. N. Y. State Mus. Nat. Hist. (Museum edit.), p. 129, Plate 13, Figs. 1–4.
1881. W. and Sp.; Revision Palæocr., Part II., p. 103.
1882. Hall; 11th Ann. Rep. Geol. and Nat. Hist., Ohio, p. 257, Plate 12, Figs. 1–4.

Calyx to the bases of the arms pyramidal; the sides slightly convex; the fixed brachials formed into broad rounded ridges, which pass up to the arms; interradial spaces somewhat concave, except at the anal side where the median portion is slightly bulging and angular. Surface of plates covered by fine undulating striæ or series of granules, about twelve of which traverse the lower half of the radials to the basals; another set passes up to the costals, and a third and fourth transversely to the sides of adjoining radials.

Each line of the transverse sets meets one of the longitudinal lines at right angles or less, and the apices of these angles fall into lines from the centre to the corners of the plates.

Basals large, forming a flat basin; column facet small and slightly projecting; the upper margins distinctly pentangular. Radials large, even for the genus. Costals curved like arm plates; the first less than one fourth the size of the radials. The first palmar, which bends slightly outward, included in the calyx. Structure of arms unknown, but there were apparently two arms to the ray. Interbrachials in two ranges, composed at the regular sides of one plate each, of which the second is considerably smaller. The anal side, which is much wider, is composed of three plates in the first row; the median one larger and wedged in between the sloping sides of the radials; the second range consists of five smaller plates, irregularly arranged, and followed by still smaller pieces.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

*Remarks.* — This species is allied to *M. ornatus*, but differs in the proportions of the plates and the absence of radial ridges. The specimen figured by Hall in the 20th Rep. of N. Y. State Cabinet on Plate 10, Fig. 7, under *M. striatus*, seems to us to differ essentially from that species in the proportions of the plates, and may even belong to a different genus.

### Macrostylocrinus fasciatus Hall.

*Plate XXII. Fig. 13.*

1876. *Cyathocrinus fasciatus* — Hall; Doc. edit. 28th Rep. N. Y. State Museum Nat. Hist., Plate 13, Figs. 5 and 6 (without description).
1879. *Macrostylocrinus fasciatus* — Hall; Mus. edit. of same Rep., p. 130 · and 11th Ann. Rep. Geol. and Nat. Hist. Ohio, 1882, p. 258, Plate 12, Figs. 5 and 6.

Calyx subovoid; height to width as ten to seven; rounded to two thirds the length of the radials, cylindrical above; arm bases but little projecting; ventral disk almost flat. Surface of plates densely covered by fine, waving striæ, which radiate in fascicles from the basals to a place a little above the centre of the radials, whence other bundles pass out to the interbrachials and adjoining radials. In addition to the striæ, the surface is marked by indistinct ridges, which follow the median line of the fascicles, and produce a well defined stellate prominence upon the basal cup and upon each radial and first interbrachial plate. The ridges upon the costals are the most prominent, and increase in width on approaching the arm bases.

Basals large, forming a rounded cup, with a narrow columnar attachment. Radials unusually large, fully four times the size of the costals, and about three times as long; very little sloped to meet the first interbrachial. First costals somewhat larger than the second. The two proximal palmars incorporated into the calyx, the others free. Arms ten. Interbrachials comparatively small, one and two at the regular sides; the anal side wider, and composed of three plates in the first row. Ventral disk constructed of small irregular pieces.

*Horizon and Locality.* — Same as last.

*Remarks.* — Hall's figures 5 and 6, on Plate 13 of the 28th Rep. N. Y. State Museum, are incorrect and misleading. The first costals are represented twice as large as they actually are, and the ornamentation is also somewhat different in the specimens. In the 20th Rep. of the same series, Plate 10, Fig. 1, Hall figures a cast from the Niagara group of Racine, Wisc., described on page 379 under the name of *Actinocrinus* (*Saccocrinus*) *semiradiatus*, which may possibly be a large example of this species.

### **Macrostylocrinus granulosus** (Hall).

*Plate XXII. Figs. 15a, b.*

1879. *Macrostylocrinus striatus*, var. *granulosus* — Hall; 28th Rep. N. Y. State Mus. Nat. Hist. (Museum edit.), p. 129.
1885. *M. striatus*, var. *granulosus* — W. and Sp.; Revision Palæocr., Part III., p. 102.

A more slender species than the preceding. Dorsal cup obconical; its sides nearly straight, spreading gradually and uniformly upwards; cross-section at the top of the costals decidedly pentangular; the basals and all plates following the rays marked by broad, rounded ridges. Another prominent ridge passes from the anus downward to the middle of the proximal anal plate, where it bifurcates to adjoining radials. Narrower ridges connect the radials laterally, and form a well defined boundary line between the upper and lower portions of the dorsal cup. The general surface is covered by fine wrinkles and indistinct striæ; those following the radials and costals longitudinally arranged, the others meeting within the middle of the plates.

Basals and radials smaller than in the preceding species; the latter plates about as wide as long, subquadrangular, and but very little sloped at the upper corners. First costals less than two thirds the length of the radials, and considerably narrower; second costals shorter and narrower than the first, their upper angles acute. Arms two to the ray, free above the first plate, which is longer than wide. The arms, according to Hall, are long, slender, and simple. Regular interbrachials slightly convex; arranged: 1, 2, 3. Anal interradius much wider, composed of three plates in the first range; the middle or anal plate longer than the two at the sides and followed by a second anal piece, of which the top is on a level with the top of the interbrachials of the third range. Structure of ventral disk unknown.

*Horizon and Locality.* — Same as last.

*Remarks.* — Prof. Hall made this species a variety of *M. striatus*. It is, however, sufficiently different to be recognized as a distinct species, which we believe is more nearly related to *M. fasciatus* than to *M. striatus*.

**Macrostylocrinus Meeki** (Lyon).

*Plate XXII. Figs. 16a, b.*

1861. *Actinocrinus Meeki* — Lyon; Proceed. Acad. Nat. Sci. Phila., p. 411, Plate 4, Figs. *4a, b.*
1881. *Macrostylocrinus Meeki* — W. and Sp.; Revision Palæocr., Part II., p. 103.

Calyx subglobose, about as wide as high; cross-section slightly pentangular. A well defined ridge rises from the column, follows the median line of the various radial plates, and passes into the arms. The ridge, which is rather obscure upon the basals, gradually increases in size, and grows quite prominent upon the costals. Smaller ridges proceed from the centre of the radials to the interbrachials, and form with the larger ridges numerous obscure triangles. The inner spaces of these triangles are occupied by fine closely arranged striæ, which form additional triangles one within the other; there being five such sets of triangles around the column, which extend to the middle of the radials, and are larger and better defined than any of the others.

Basals forming a shallow basin, rounded at the bottom; the column facet slightly concave. Radials fully four times as large as the first costals, and as long as wide. First costal narrower than the second, and fully twice as wide as long; the second somewhat larger, its sides spreading rather abruptly upwards, the sloping upper faces concave and forming an acute angle. First interbrachial large, a little longer than wide, resting against the distinctly sloping sides of the radials, and rising to the top of the second costals; the succeeding plates much smaller. The arrangement of plates at the anal side is not known; neither is the construction of the ventral disk nor the structure of the arms.

*Horizon and Locality.* — Niagara group; Jefferson Co., Ky.

*Types* in the Knapp collection at the Borden Institute of New Providence, Ind.

### Macrostylocrinus fusibrachiatus RINGUEBERG.

*Plate XXIII. Figs. 9 & 10.*

1881. RINGUEBERG; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 119, Plate 5, Fig. 4.
1885. W. and Sp.; Revision Palæocr., Part III., p. 102.

Larger than the preceding species, and proportionally broader. Dorsal cup apparently bowl-shaped — the exact form not being ascertainable owing to the crushed condition of the specimen; interradial spaces depressed; section subpentagonal; surface of plates covered by numerous small, irregularly arranged granules.

Basals of moderate size, forming together a rapidly spreading pentagonal cup; the column facet surrounded by a small rim, formed by a row of small, closely arranged nodes. Radials large, wider above than below, subquadrangular; the upper corners slightly truncate. First costals quadrangular, less than half the size of the radials, nearly twice as wide as long. Second costals smaller than the first, and considerably shorter. Distichals free after the second plate. Arms ten, long, massive, widest in the middle, and tapering at both ends. The two fixed distichals are followed by a few much shorter cuneate pieces, and the latter by two rows of short transverse plates, alternately arranged and united by a zigzag suture. Regular interbrachials five in three ranges; the first plate large and oblong; the arrangement of the anal side unknown. Column round; the edges of the nodal joints surrounded by small nodes.

*Horizon and Locality.* — Niagara group; Lockport, N. Y.

*Type* in the collection of Dr. E. N. S. Ringueberg.

*Remarks.* — The specimen illustrated by Fig. 10 differs slightly from the type, being smaller, and having a more elongate cup, less massive arms, and proportionally higher costals. But as it is of the general habitus of this species, we take it to be a young specimen of the same.

## MELOCRINUS Goldfuss.

1826. Goldfuss; Petref. Germaniæ, Vol. I., p. 197.
1838. Agassiz; Mém. de la Soc. des Sci. natur. de Neuchatel, Vol. I., p. 196.
1838. Goldfuss; Nova Acta, Acad. Leopoldina, Vol. XIX., I., p. 339.
1841. Müller; Monatsber. d. Berlin. Akademie, p. 209.
1849. D'Orbigny; Cours élément., Vol. II., p. 140.
1852. Quenstedt; Handb. d. Petrefactenkunde (Ausg. I.), p. 620.
1855. Roemer; Lethaea Geognostica (Ausg. 3), p. 250.
1857. Pictet; Traité de Paléont., Vol. IV., p. 325.
1862. Dujardin and Hupé; Hist. natur. des Zoophytes, p. 144.
1867. Schultze; Monogr. Echinod. Eifl. Kalk., p. 61.
1878. Angelin; Iconogr. Crin. Suec., p. 19.
1879. Zittel; Handb. d. Palæont., Vol. I., p. 371.
1881. W. and Sp.; Proceed. Acad. Nat. Sci. Phila., p. 292
1881. W. and Sp.; Revision Palæocr., Part II., p. 118.
1882. De Loriol; Paléont. Française, Tome XI. (Crinoïdes), p. 58.
1885. W. and Sp.; Proceed. Acad. Nat. Sci. Phila., p. 326.
1885. W. and Sp.; Revision Palæocr., Part III., p. 104.
1885. Quenstedt; Handb. d. Petrefactenkunde (Ausg. 3), p. 957.
1889. S. A. Miller; N. Amer. Geol. and Paleont., p. 261.

Syn. *Ctenocrinus* Bronn; 1840, Jahrb., p. 542; also Müller, 1855, Verh. naturh. Verein, Vol. XII., p. 16, and Neue Echinod. Eifl., Kalk., p. 255; also Follmann, 1857, Unterdevonische Crinoideen, p. 14.

Syn. *Castanocrinus* Roemer; 1855, Leth. Geogn. Vol. II., p. 252.

Syn. *Mariacrinus* Hall (in part); 1857, Paleont. N. Y., Vol. III., p. 104.

Syn. *Cytocrinus* Roemer; 1860, Silur. Fauna West. Tenn., p. 46.

Syn. *Clonocrinus* Oehlert; 1879 (not Quenstedt), Soc. Géol. de France (sér. 3), Vol. VII., p. 9.

Syn. *Turbinocrinites* Troost; 1850, List of Crin. Tenn. (not defined).

Syn. *Astrocrinites* Conrad; Ann. Geol. Rep. N. Y. of 1840 to 1841 (not Cumberland, 1826, nor Austin, 1842, nor Etheridge, Jun., 1876, nor *Asterocrinus* Münster, 1839, nor Lyon, 1857, nor *Astrocrinus* Ether. and Carpenter, 1886).

Calyx obconical, subglobose or pyriform; the rays extended into free tubular appendages bearing arms on both sides. Basals four, unequal; three of them quadrangular, the anterior one larger and pentangular. Radials in contact laterally; four of them heptagonal, the anterior one, which rests squarely upon the anterior basal, hexagonal. First costal hexagonal, the second, which is axillary, generally pentagonal; the sloping faces of the latter may be equal and support two rows of distichals, or unequal, when only the longer inner face is followed by distichals, the shorter outer one giving off the proximal arm. In the former case, which is the general rule, the distichals constitute parts of the calyx, and both series terminate in axillaries, which give off toward the inner side of the ray in a nearly vertical direction an indefinite number of brachials of successive orders, and toward the outer side a sloping arm from each order. The plates of the different orders are short and consist of two parallel series, which form two arm-bearing trunks. The two trunks, as a general rule, meet laterally by suture, and form together rigid tubular appendages, which pass out from the calyx upwards. In some cases the connection of the appendages is interrupted for short distances, but, so far as known, all of them come together, and are united toward the upper part. From these appendages throughout their full length, at certain intervals, and from opposite plates (not alternately) are given off well defined biserial arms, bearing pinnules on alternate sides. A slight departure in the construction of the main trunks occurs among species in which the proximal arms are given off already from the first axillaries, *i. e.*, from the costals. In these species the trunks at the dorsal surface are composed of but a single series of plates, and the pinnule-bearing arms are arranged alternately as in *Steganocrinus sculptus*. The ventral surfaces of the appendages are roofed over in all cases by rigid covering plates.

Interbrachials numerous; the first placed upon the sloping upper faces of the radials, followed by two plates in the second row at the four regular sides, three plates at the anal side, and a greater or less number of irregular plates above, which meet with the interambulacral plates. Ventral disk highly elevated or scarcely convex; the orals in some species largely developed, in others indeterminable. Anus excentric and generally — perhaps always — extended into a small tube.

Column round, composed of alternate long and short joints; axial canal small.

*Distribution.* — *Melocrinus* ranges from the Upper Silurian to near the close of the Devonian, and is well represented both in America and Europe.

*Remarks.* — The genus *Melocrinus* holds the same relation to *Mariacrinus* that *Steganocrinus* does to *Actinocrinus*, and *Eucladocrinus* to *Platycrinus*. In all these types the construction of the calyx remains relatively almost unchanged, while a remarkable modification occurs in the brachial appendages, which are extended into tubular rays with an indefinite number of semi-free brachials, giving off arms.

Several attempts have been made to subdivide *Melocrinus* into two or three genera. Roemer, in 1855, proposed the name *Castanocrinus* for species with a central or subcentral anal opening, retaining *Melocrinus*, with *M. hieroglyphicus* Goldfuss as type, for species with a lateral opening. Our examination of the various species leads us to doubt whether such a division can be practically upheld. We agree with Schultze * that the anus is never central in this genus, nor in any case actually lateral, but its position is

* Monogr. Eifl. Kalkes, p. 63.

always more or less excentric. Neither can the presence or absence of interdistichals, unless accompanied by other distinctive characters, be considered sufficient for generic separation, as proposed in the case of *Ctenocrinus* Bronn.* Those plates are mere auxiliary pieces, which may be present or absent in the same species.

*Turbinocrinites* Troost was proposed in MS., according to Hall,† for a species which was said to have the first anal plate on a level with the radials; but Troost's typical species, *Melocrinus Verneuili*, had no such plate, or Hall could not have stated that the anal area was but slightly distinct from the other four.

*Cytocrinus* was described by Roemer with three (?) basal plates — the exact number not having been ascertained. A good specimen in our collection from Roemer's typical locality plainly shows four plates, and we have no doubt the species is a *Melocrinus*.

*Phillipsocrinus* McCoy is described with four basals, succeeded by seven plates in the next ring, which shows that it is an abnormal specimen. If it is, as we think, an Actinocrinoid, the abnormal seventh plate may have necessitated the presence of a fourth basal.

In addition to the species herein figured and described, we note the following: *Melocrinus obpyramidalis* Winchell and Marcy, *M. Verneuili* Hall (not Oehlert). and *M. nodosus* Hall, which were described from unsatisfactory natural casts. Neither can *M. Pratteni* (*Forbesiocrinus Pratteni*) McChesney, which was defined from a fragmentary specimen, or *Melocrinus sculptus* Hall, of which only the basal plates are known, or *M. brevidactylus* Hall, which was figured but not described, and the figure not properly published, be regarded as good species.

* The genus *Ctenocrinus* was at first incorrectly defined. It was described by Bronn, 1840 (Jahrbuch, p. 542), with three basal plates, and this number was confirmed by Roemer (Lethaea Geogn., 1855, p. 251). Subsequently de Koninck considered the genus identical with *Pradocrinus* De Verneuil, which actually has three basals. Joh. Müller (Verhandl. naturh. Verein, 1855) admits more than three basals, probably five, and in 1857 (Neue Echinod. Eifl. Kalk., p. 255), asserts positively the presence of five basals. He compared *Ctenocrinus* with *Glyptocrinus* Hall, and supposed both to have "parabasalia." Schultze afterwards, in his Monograph, p. 63, proved from more perfect specimens that *Ctenocrinus typus* has but *four* basals, and no infrabasals, and referred that species to *Melocrinus*. Follman, in his article on the "Unterdevonischen Crinoideen," Verhandl. Naturh. Verein, 1887 (private ed., p. 14), revised the genus *Ctenocrinus* with four basals, but pointed out no characters by which it may be distinguished from *Melocrinus*.

† 28th Rep. N. Y. State Mus. Nat. Hist. (Museum edit.), p. 139.

## **Melocrinus nobilissimus** (Hall).

*Plate XXIII. Figs. 1a, 2, 3.*

1859. *Mariacrinus nobilissimus* — Hall; Palæont. N. Y., Vol. III., p. 105, Plate 2, Figs. 1-4, and Plate 2A, Fig. 1.
1881. *Melocrinus nobilissimus* — W. and Sp.; Revision Palæocr., Part II., p. 122.

A rather large species. Dorsal cup higher than wide, obconical, obtusely pentangular above the costals owing to a depression in the upper portions of the interradial spaces. The tubular appendages supporting the arms consisting of two contiguous trunks, which are composed dorsally of two rows of plates. Plates marked with obscure radiating ridges; the suture lines well defined, with a shallow pit at each angle.

Basals wider than long, formed into a small subcylindrical cup, not projecting beyond the column. Radials larger than the costals, about as wide as long. The second costals with an obtuse angle above. Distichals 3 × 10, about half the size of the costals, the upper ones axillary and supporting upon their outer sloping faces a lateral arm, of which the four or five proximal plates, which are longer, are incorporated into the calyx; while the inner sloping faces are followed by a row of from six to seven palmars. The latter form a vertical line with the distichals, and the plates of adjoining divisions are connected laterally, except the two proximal ones of each side, between which are interposed small irregular interdistichals. The fourth and fifth orders of brachials consist of five plates, the sixth and all orders to the ninth of four, the succeeding ones of three, and those near the top of but two pieces. The brachials are arranged longitudinally, and connected suturally with those of the opposite branch, so as to form a compound, free tubular appendage, from which the arms are given off at opposite sides, the axillaries supporting on their longer sides the next order of brachials, and on their shorter ones an arm. There are about thirty arms to each side of the ray, rising to the same general height; all composed from the second plate up of two series of interlocking pieces, and all pinnule-bearing. Regular interradial spaces narrow but long; the first plate rests within a deep notch between two radials, and is somewhat larger than the others; the succeeding ones are not arranged in horizontal rows, but alternate with one another; they are hexagonal, and the upper lateral faces of the one plate rest against the lower lateral faces of the other, thus forming two longitudinal rows side by side, each composed of about twelve plates, which decrease in size upward. Anal interradius considerably wider, and flattened instead of being grooved as in the case of the other four; the first plate is the largest, and is followed by three pieces in the second row, and these by three or four pieces in the succeeding rows. Interdistichals four, rather large and longitudinally arranged; the upper one resting between the two proximal palmars. Nothing is known of the ventral disk, nor of the anus. Column large, round, composed near the calyx of moderately long joints alternating with shorter ones; suture lines distinctly waving.

*Horizon and Locality.* — Pentamerus limestone; Litchfield, Herkimer Co., N. Y., and apparently also found in the Niagara group of Western Tennessee.

*Types* in the American Museum of Natural History, New York.

### Melocrinus pachydactylus (Conrad).

*Plate XXIII. Figs. 4 and 5, and Plate XXIV. Figs. 4a, b.*

1841. *Astrocrinites pachydactylus* — Conrad; Ann. Rep. Palæont. N. Y., p. 34. Also Mather 1843; Geol. Rep. N. Y., p. 246.
1859. *Mariacrinus pachydactylus* — Hall; Palæont. N. Y. Vol. III., p. 107, Plate 3, Figs. 1–4.
1881. *Melocrinus pachydactylus* — W. and Sp.; Revision Palæocr., Part II., p. 122.
Syn. *Actinocrinus polydactylus* Bonny (not S. A. Miller); Schenectady Reflector of 1835.
Syn. *Mariacrinus paucidactylus* Hall; Palæont. N. Y., Vol. III., p. 109, Plate 3, Fig. 5.
Syn. *Melocrinus paucidactylus* — W. and Sp.; Revision Palæocr., Part II., p. 122.

Smaller than the preceding species; dorsal cup shorter and with convex sides; interradial spaces not grooved, although slightly impressed in the upper portions; the radiating ridges upon the surface much more conspicuous, and ending in a node at the centre of the plates; the arms given off at greater intervals, and the pinnules less closely packed together than in that species.

Basals formed into a short spreading cup, of which the lower margin is slightly projecting. Radials and costals of nearly equal size, as wide as long; both covered by a broad, flattened ridge, which bifurcates on the second costal and follows the distichals. Narrower ridges pass out to the interbrachials. Distichals $3 \times 10$, smaller than the costals. The axillaries support upon the inner sides of the ray from seven to eight palmars, which are laterally connected; at their outer sides the proximal arms, of which the five lower plates are considerably the longest, and form part of the calyx. The two lower palmars of each side are longer than the upper ones, and those of the one division are separated from those of the opposite side by a small interdistichal. The surface of these plates is covered by radiating ridges and nodes; while that of the succeeding ones is without ornamentation, and the plates are transversely arranged. The brachials of the fourth order consist of six plates, those of the succeeding ones of five, rarely four (so far as observed); all transversely arranged, and suturally connected with their fellows of opposite sides, forming five long tubular, arm-bearing trunks. The arms of this species are more slender than in the preceding one, and slightly more tapering, the pinnules longer; they are flattened on the back, and the surface is corrugated. Interradial spaces composed of about twelve plates arranged in two longitudinal rows, the plates alternating with one another. The anal interradius and ventral disk are not visible in the specimens.

*Horizon and Locality.* — Schoharie Co., N. Y.; Lower Helderberg group.

*Types* in part in the American Museum of Natural History, New York.

### **Melocrinus bainbridgensis** Hall and Whitfield.

*Plate XXII. Figs. 4a, b, c, and Plate XXIV. Fig. 5.*

1875. *Melocrinus* (*Ctenocrinus*) *bainbridgensis* — Geol. Surv. Ohio, Palæont., Vol. II., p. 158, Plate 13, Figs. 2 and 3.
1881. *Melocrinus bainbridgensis* — W. and Sp.; Revision Palæocr., Part II., p. 121.
Syn. *Melocrinus Clarkei* Williams; 1882, Proceed. Acad. Nat. Sci. Phila., p. 31.

Specimens above medium size. Dorsal cup as high as wide, rather rapidly spreading; sides somewhat convex; cross-section pentangular. Plates slightly elevated, beveled at their margins; the middle part a little depressed, and covered with a system of confluent granules; the suture lines grooved.

Basals forming a low cup with a small rim around the lower margin, which is notched at the interbasal sutures; axial canal pentalobate. Radials and costals wider than long, decreasing in size upwards. Distichals $3 \times 10$, those of the same ray in contact laterally, interdistichals not being represented; the proximal one less than half the size of the second costal, and as long as wide; the two others much shorter. The third plate, which is axillary, supports upon its inner face the next order of brachials, at the outer the proximal arm which is free from its origin. The brachials of the succeeding orders also consist of three pieces, which are transversely arranged, and those of the same ray are laterally connected, forming trunks from which arms are given off at every third plate. The trunks taper upward, and are deeply grooved along the line of contact of the two branches. Arms thin, thread-like, with closely packed pinnules. Regular interbrachials: 1, 2, 3, and others above, which gradually intermingle with the interambulacrals. The first interbrachial of the anal side is somewhat the largest, and is followed by three plates in the second row, which form an arch, and by four pieces in the third and fourth rows. Ventral disk low, depressed-pyramidal, apparently surmounted by a subcentral anal tube; the plates more or less uniform, of about medium size, and somewhat convex.

*Horizon and Locality.* — In a limestone layer, six inches in thickness, above the base of the Black Slates, Bainbridge, Ross Co., O., and at Canandaigua, N. Y., in rock of about the same age.

*Type* in the Ohio State collection, Columbus.

*Remarks.* — Prof. J. M. Clarke of Albany had the kindness to send us *gutta-percha* casts of the types of *Melocrinus Clarkei* Williams, which we regard as identical with *M. bainbridgensis.*

**Melocrinus gracilis** W. and Sp. (nov. spec.).

*Plate XXII. Fig. 5.*

A rather small species, of the type of *Melocrinus* (*Ctenocrinus*) *stellaris* Roemer. Dorsal cup obpyramidal; the radials and costals strongly curved so as to form broad, very conspicuous longitudinal ridges with a small tubercle at the centre of each plate, those of the axillaries being the longest and sharpest. Interbrachial spaces depressed, giving to the section across the second costals a sharply pentangular, somewhat stelliform outline.

Basal cup low, broadly truncate at the bottom, its lower edges slightly projecting beyond the column; the upper angles turned abruptly upwards. Radials and costals nearly equal in size, wider than long, but the curvature makes them appear to be longer than wide. Distichals $2 \times 10$, rounded like arm plates; short, transversely arranged, those of the same ray separated by one or two minute interdistichals, which rest within the bottom of a shallow pit. The arm trunks bend outward, are heavy, and composed of two rows of short pieces. The arrangement of the arms cannot be ascertained, as in the single specimen the trunks are preserved only to the fourth plates, and of the arms only fragments of a single one. Interbrachials numerous, slightly decreasing in size upward; arranged: 1, 2, 3, 3, *etc.* They are somewhat convex and ornamented with obscure radiating ridges, which connect with the interambulacral plates. Ventral disk elevated, and, so far as known, composed of rather small pieces. Form and position of anus unknown. Column round, strong; the nodal joints projecting, the intervening ones knife-like.

*Horizon and Locality.* — Hamilton group; Canandaigua Lake, N. Y.

*Type* in the collection of Prof. J. M. Clarke, now in the State Museum at Albany.

**Melocrinus Tiffanyi** W. and Sp. (nov. spec.).

*Plate XXII. Figs. 7a, b.*

Calyx pyriform; the sides nearly straight from the top of the basals to near the bases of the arms; the tegmen depressed-hemispherical; cross-section, as seen from above, obtusely pentangular. Surface of plates ornamented by faint ridges, radiating from near the centre of the plates to the centre of adjoining ones.

Basals projecting laterally, forming four conspicuous, elongate nodes; the lower part somewhat excavated for the reception of the column. Radials and costals gradually decreasing in size upwards, about as long as wide; the second costals not more than half the size of the radials. Of the distichals two plates are preserved; the lower one fully one half smaller than the preceding axillary; the second short, shaped like an arm joint and curving outwards. There are no interdistichals, all plates of the arm trunks being in contact laterally. Interradial areas on a plane with the radials and costals; the first interbrachial the same size as the radials, and followed in the type specimen by two plates at three of the sides, but in the posterior and right antero-lateral interradius by three, and these by numerous rows of from three to four plates, which connect with the disk pieces. Ventral disk depressed-hemispherical, the plates very uniform, rather large, having the size of the third row of interbrachials. They are ornamented like the plates of the dorsal cup, but are a little more convex. There are apparently no orals. Anus excentric, probably connected with a tube. Arms unknown; column round.

*Horizon and Locality.* — Hamilton group; New Buffalo, Iowa.

*Type* in the collection of Mr. S. A. Tiffany of Davenport.

**Melocrinus Calvini** W. and Sp. (nov. spec.).

*Plate XXII. Fig. 6.*

Similar to the preceding species, but the sides of the dorsal cup convex, and the general form of the calyx subovoid; the basals less projecting; the radials, fixed brachials and interbrachials — the latter to the third row — crowned by a large, rather conspicuous rounded node without other ornamentation; the upper interbrachial and interambulacral plates a little convex.

Basals projecting laterally, and forming four rather conspicuous nodes around the columnar attachment which is a little projecting. Radials and costals longer than wide. The distichals of the same ray in contact laterally. Regular interbrachial spaces large, but slightly depressed between the arm trunks; the plates arranged: 1, 2, 3, 3, the upper ones insensibly connecting with the plates of the ventral disk. Anal interradius widest, having three plates in the second row. Ventral disk short; the plates rather small and of uniform size; orals apparently unrepresented. Anus excentric, probably at the end of a narrow tube.

*Horizon and Locality.* — Hamilton group; Johnson Co., Iowa.

*Type* in the collection of Prof. S. Calvin of Iowa City, in whose honor this rare species is named.

**Melocrinus oblongus** W. and Sp. (nov. spec.).

*Plate XXII. Figs. 9 and 12.*

A rather slender species of less than medium size. Dorsal cup obconical; the sides straight to the top of the second costals, whence the rays turn outward and form distinct lobes around the calyx, which give to the section a decidedly pentalobate outline. Plates convex, a little nodose, but without ornamentation.

Basals small, subequal, notched at the sutures; the lower face but slightly truncate, and very little excavated. Radials and first costals generally longer than wide, especially the former; the second costals often as wide as long. Distichals $2 \times 10$, the two upper ones axillary and separated by a small interdistichal. The arm trunks not preserved in the specimens, but as there are two distichals, the trunks must have been formed of two rows of plates. The first interbrachial as large as the first costal; succeeded by rows of 2, 3, 3, and three plates, which meet the interambulacrals. Anal interradius a little wider, with three plates in the second row, and four in the third. Ventral disk low, irregularly convex; the ambulacral spaces slightly elevated; the plates — orals included — almost of uniform size. Anus subcentral; at the end of a tube.

*Horizon and Locality.* — Niagara group; near Louisville, Ky., and St. Paul, Ind.

*Types* in the collection of Wachsmuth and Springer.

*Remarks.* — This form was regarded by Roemer * as specifically identical with his *Cytocrinus lævis*, which comes from the same horizon in Tennessee, and resembles it in general form; but the arm trunks of that species are composed of single joints, and it has a smaller number of interbrachials.

### **Melocrinus Roemeri** W. and Sp. (nov. spec.).

*Plate XXII. Figs. 11a, b.*

Syn. *Cytocrinus lævis* — Roemer; 1860. Silur. Fauna West. Tenn., p. 46, Plate 4, Figs. 2*a*, *b*, *c*.
Syn. *Ctenocrinus lævis* — Shumard; 1866. Trans. Acad. Sci. St. Louis, p. 361.
Syn. *Melocrinus lævis* (not Goldf.) — W. and Sp. (in part); 1881. Revision Palæocr. Part II., p. 122.

Calyx moderately small, turbinate; dorsal cup about as wide as high, gradually spreading to the arm bases, which are formed into five very conspicuous lobes, giving to the calyx, as seen from above, a decidedly stellate outline. Plates without ornamentation, a little concave, except the median line of the radial plates, which is obtusely angular. The radial appendages from which the arms are given off composed of a single series of plates.

Basals rather large, subequal, forming a shallow cup, which is slightly truncate at the lower end. Radials twice as large as the first costals, hexagonal, about as wide as long; their upper sloping faces a little larger than the corresponding lower ones. Second costals very small and curved like arm plates; their upper sloping faces unequal, that toward the outer side of the ray much the longest, and supporting a distichal, the inner one the first arm plate. The trunks, which consist of a single series of plates, give off the arms at intervals from alternate sides, not from opposite plates as in species with a double series. Interbrachial spaces wide, the first plate large, succeeded by two rows of two and three plates respectively, which are followed by disk plates. The two outer plates of the upper row curve outward and form the sides of the lobes. At the anal side the first plate is larger, and followed by

* Silur. Fauna West. Tennessee, 1860, p. 48.

three plates in the second row, and four in the third. Ventral disk depressed, pentagonal; the ambulacral regions slightly raised above the general level; the plates without ornamentation, almost flat, and the sutures difficult to see.

The disk ambulacra are completely subtegminal; the orals apparently unrepresented, and the anus is at the end of a large tube, which bends toward the posterior side.

*Horizon and Locality.* — Niagara group; associated with *Astræospongia meniscus.* Decatur Co., Tenn.

*Type* in the collection of Wachsmuth and Springer.

*Remarks.* — Roemer described this species as *Cytocrinus lævis*, making it the type of a new genus. He supposed it had three basals, and he did not understand its arm structure, which is evidently that of *Melocrinus.* We refer the species to the latter genus, but are compelled to change the specific name, as Goldfuss in 1826 described a *Melocrinus lævis* from the Eifel, and propose for it *Melocrinus Roemeri.* Roemer originally included in his species two forms, the typical one from the Niagara group of Western Tennessee, and another from the same horizon of near Louisville. The latter has been described by us as *Melocrinus oblongus.* The two species resemble each other in form, but *M. oblongus* is considerably larger, the calyx contains many more plates, and the radial appendages are composed of two rows of brachials in place of one.

### Melocrinus obconicus Hall.

*Plate XXII. Figs. 10a, b, c.*

1863. *Melocrinus obconicus* — Hall; Trans. Alb. Inst., p. 206.
1875. *Melocrinus obconicus* — Hall; 28th Rep. N. Y. State Mus. Nat. Hist., p. 138, Plate 14, Figs. 11-14.
1881. *Melocrinus obconicus* — Hall; 11th Ann. Rep. Geol. Ind. by Collet, p. 269, Plate 13, Fgs. 11-14.
1881. *Mariacrinus obconicus* — W. and Sp.; Revision Palæocr., Part II., p. 116.

Of medium size. Calyx obconical, about as wide as high; gradually expanding from the top of the basals to the bases of the free appendages, where it is distinctly lobed. Plates covered by numerous radiating ridges, which pass out from the middle of the plates to the sides and angles, meeting those of adjoining plates; the ridges passing up and down the radial plates wider and somewhat higher. Besides these ridges the whole surface of the plates — that of the ridges included — is finely corrugated, which adds greatly to the beauty of the species.

Basals projecting, forming a short, indistinctly quadrangular, almost cylindrical cup. Radials and costals of about equal size, and all nearly as long as wide. Distichals two, the two divisions separated by one or two interdistichals. Palmars apparently not united laterally, and there may have been two appendages to each ray Interradial spaces depressed in the upper portions; arranged: 1, 2, ² with numerous plates above, which connect with others in the disk. A..d area somewhat the widest, and with three plates in the second row. Ventral disk almost flat; composed of very uniform, slightly convex pieces. Anus excentric, probably without a tube.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

*Type* in the American Museum of Natural History, New York.

**Melocrinus parvus** W. and Sp.

*Plate XXII. Fig. 8.*

1892. W. and Sp.; Amer. Geologist (September number), Vol. X., p. 144.

A small and very slender species of the type of *Melocrinus Roemeri*, having like that species five uniserial radial appendages. Dorsal cup obpyramidal, the interradial spaces deeply depressed, and the cross-section at the top of the costals distinctly pentalobate. The plates a little convex and covered with obscure ridges.

Basal cup almost cylindrical, its upper end slightly the widest, the lower face completely covered by the column; the plates as high as the radials, and the interbasal and basi-radial sutures distinctly grooved. Radials a little longer than wide. First costals of the same proportions as the radials. Second costals smaller, proportionally shorter, and irregularly axillary; one of their upper faces short and giving off an arm, the other a row of distichals, which are followed by higher orders of brachials, and arms given off at intervals from opposite sides. Interbrachials three at the regular sides, and four at the anal side, the latter having three plates in the second row against two at the other sides. Ventral disk convex, the interambulacral spaces a little depressed; composed of moderately large, slightly convex plates. Arms excentric.

*Horizon and Locality.* — Niagara group; St. Paul, Ind.

*Type* in the collection of Wachsmuth and Springer.

*Remarks.* — This species differs from *M. Roemeri* in the narrower and less spreading base, in the proportions of the radials and costals, and in the convexity of the plates.

### Melocrinus æqualis S. A. Miller.

1892. Adv. Sheets 18th Rep. Geol. Surv. Indiana, p. 48, Plate 5, Figs. 11 and 12.

A moderately small species. Dorsal cup obpyramidal, decidedly pentangular at the arm bases, deeply sunken interradially. All plates of the calyx heavy and tumid; those of the dorsal cup covered with short ridges at their margins, one to each side, the median portions of the plates smooth. Suture lines well marked. The radial appendages directed almost horizontally.

Basals nearly equal, longer than wide, the sides very little expanding. Radials as long as the basals, a little wider than long. First costals hexagonal, almost as large as the radials; the second smaller and irregularly axillary, giving off at the shorter side an armlet, and at the longer the next order of brachials. Rays free above the costals, and evidently composed of a single row of plates, with arms given off at alternate sides. Interradial areas probably alike; the first interbrachial nearly as large as the adjoining costal, followed by two and three smaller plates, of which the latter occupy the arm regions. Plates of the tegmen very large, composed of only two rings, the upper supporting a massive anal tube, composed of tumid or nodose plates.

*Horizon and Locality.* — Niagara group, St. Paul, Ind.

*Remarks.* — This species resembles *M. parvus* in having simple free rays, but differs from it distinctly in the form of the calyx, the greater convexity of the plates, in having a much stronger anal tube, and the rays directed horizontally.

Our description was made after Miller, and from fragmentary specimens in our collection.

## II. DOLATOCRINITES.

SYMMETRY OF THE DORSAL CUP UNDISTURBED BY ANAL PLATES.

### TECHNOCRINUS Hall.

1859. Hall; Palæont. New York, Vol. III., p. 139.
1879. Zittel; Handb. der Palæont., Vol. I., p. 372.
1881. W. and Sp.; Revision Palæocr., Part II., p. 116 (Proceed. Acad. Nat. Sci. Phila., p. 290).
1889. S. A. Miller; N. Amer. Geol. and Palæont., p. 286.

Calyx large; symmetry perfectly pentahedral up to the arm bases, except a slight irregularity in the basal cup. Basals four, somewhat unequal, arranged as in *Melocrinus.* Four of the radials heptagonal, the anterior one hexagonal. Costals two; the first hexagonal, the second generally pentagonal. Distichals 1×10, all axillary. The first palmar, and sometimes the second, takes part in the calyx; the succeeding ones being arm plates. Arms long, simple, straight, biserial; fringed by good-sized pinnules, which are in contact. Interbrachials three or four, but no interdistichals. Structure of ventral disk and anus unknown. Column round; tapering.

*Distribution.* — The genus is known only from the Oriskany Sandstone of Maryland.

*Type* of the genus: *Technocrinus spinulosus* Hall.

*Remarks.* — *Technocrinus* differs from *Mariacrinus* and *Melocrinus* in the perfect pentamerous symmetry of its dorsal cup, and from the former in having one instead of three to four distichals, no interdistichals, and the arms arranged in an almost continuous series around the calyx; while the arms of *Mariacrinus* are arranged in groups. It differs from *Melocrinus* in having simple arms given off directly from the calyx, and not from its tubular extensions.

*Technocrinus striatus* and *T. sculptus* Hall, were described from detached basal plates.

### **Technocrinus spinulosus** Hall.

*Plate XXII. Fig. 3.*

1859. Hall; Palæont. New York, Vol. III., p. 140, Plate 85, Figs. 1-18.
1881. W. and Sp.; Revision Palæocr., Part II., p. 117.

Calyx subglobose, the arm bases slightly contracting. Plates of the dorsal cup marked by a central spine or node, surrounded by smaller nodes, which vary in number among the plates. From the nodes two to four parallel ridges pass out to the sides, and these are continued upon adjoining plates. Near the arm bases the ridges gradually disappear, and the plates are marked only by a central spine.

Basals four, of medium size, forming a shallow basin with five sets of four ridges, each set communicating with those upon the radials. Radials and costals nearly as wide as long, decreasing in size upwards; the second costal but half the size of the first. Distichals one to each side of the costal axillaries. The first palmar enclosed in the calyx. Arms twenty, stout, rounded; composed at their bases of cuneate pieces, which interlock farther up, and gradually become biserial. Interbrachials apparently four. All other parts of the calyx unknown. Column slightly pentagonal, each alternate joint provided with a node or short spine at the margin.

*Horizon and Locality.* — Oriskany Sandstone, Cumberland, Md.

*Type* in the American Museum of Natural History, New York.

### Technocrinus Andrewsi Hall.

*Plate XXIV. Fig. 3.*

1859. Hall; Palæont. New York, Vol. III., p. 141, Plate 86, Figs. 1-4.
1881. W. and Sp.; Revision Palæocr., Part II., p. 117.

A rather large species. Calyx to the arm bases hemispherical; plates moderately convex, surrounded by sets of short marginal ridges passing inward, three to four to each side of the plate, and by small pits along the sutures; the centre of the plates perfectly smooth. Basals wider than high. Radials large, about as long as wide. First costals of the form of the radials, but considerably smaller; the second still smaller, narrower as well as shorter. Distichals one, axillary; supporting in the calyx two rather large palmars, followed by several cuneate, interlocking free plates, and these by two rows of subquadrangular pieces, united by a sharply zigzag suture. Arms four to the ray, strong, flat, and of almost uniform width throughout. Pinnules contiguous. Interbrachials four or five: 1, 2, 1, 1, all comparatively large. Column round, large, tapering; the joints rather long and slightly rounded exteriorly.

*Horizon and Locality.* — Oriskany Sandstone, Cumberland, Md.

*Type* in the American Museum of Natural History, New York. The species is described and figured from a cast made from the natural mould in the rock.

## ALLOCRINUS W. and Sp.

1889. W. and Sp.; Geol. Rep. Illinois, Vol. VIII., p. 206.

Calyx small; the arms stout; symmetry of dorsal cup equilateral. Basals three, small, unequal — the left antero-lateral plate one half the smaller — forming a disk, which is almost completely covered by the column. Radials large, much wider than the costals. Costals two, rounded like arm plates. Arms uniserial, strong, simple; two to the ray, being free from the second or third distichal. Interradial spaces composed of two or three plates, of which the first is much the largest. Column small, round; axial canal narrow, pentangular.

*Distribution.* — *Allocrinus* is restricted to America. It belongs to a little group of Crinoids which is sparingly represented in this country, but of which several genera with a number of species are known to have existed during the Upper Silurian period in Sweden and England.

*Remarks.* — This genus has close affinities with *Patelliocrinus* and *Dolatocrinus*. It differs, however, from both of them in the form and size of the various calyx plates, and in having uniserial arms. It also approaches *Centrocrinus*, but this has a large and perfectly anchylosed basal disk.

### **Allocrinus typus** W. and Sr.

*Plate XXIV. Figs. 7a, b.*

1889. W. and Sr.; Geol. Rep. Illinois, Vol. VIII., p. 207, Plate XIV., Fig. 7.

Below medium size. Calyx depressed, proportionally small, sharply pentangular in outline, the arm bases projecting, the arms massive and proportionally stouter than those of any other Crinoid; the plates without ornamentation. Basals small, forming a flattened disk, which is almost covered by the column; interbasal and basi-radial sutures indistinct. Radials large, abruptly curved, the lower portions forming the rim of an inverted shallow basin, the upper half bent abruptly upward and forming together with the plates above a shallow, spreading cup with straight sides. Costals and fixed distichals short, curved like arm plates, producing upon the surface of the calyx strong, rounded ridges, which insensibly pass into the free arms. Arms ten, stout, uniserial, free above the second plate; composed of transverse joints with parallel upper and lower faces. The arms much wider midway than at either end, tapering considerably and uniformly toward the tips, but almost as much toward the calyx. Interradial spaces deeply depressed, composed of two plates vertically arranged, of which the first is the larger and nodose, and extends to the top of the costals; while the other is on a level with the fixed brachials, and forms, to some extent, a part of the ventral surface. Nothing is known of the anal aperture and the structure of the ventral disk. Column round, small; axial canal pentangular.

*Horizon and Locality.* — Niagara group; Wayne and Decatur Cos., Tenn.

*Types* in the Worthen collection, Springfield, and that of Wachsmuth and Springer.

### Allocrinus Benedicti S. A. Miller.

*Plate XXIV. Figs. 8a, b.*

1891. S. A. Miller; Adv. Sheets 17th Rep. Geol. Surv. Indiana, p. 37, Plate 7, Fig. 1.

Closely resembling the preceding species, but the dorsal cup a little smaller and less sharply angular, the plates generally more convex, and the arms not quite so stout. Dorsal cup bowl-shaped, a third wider than high, the lower end distinctly truncate, the sides convex, the plates elevated and more or less nodose.

Basals forming an equilateral pentagonal disk, which has twice the diameter of the column, and occupies the bottom of a shallow concavity; interbasal sutures indistinct. Radials large, curving gradually upwards, their upper ends at right angles to the lower. Both costals together of about the size of the radials, wider than long, the sides decidedly beveled and forming a deep groove toward the interbrachials. First costals quadrangular, the second pentangular. Distichals one in the calyx, the others free. Arms ten, so far as observed, moderately heavy; their plates quadrangular. Interbrachials one, very large, elongate, and highly convex in the middle, beveled around the margins. Structure of ventral disk unknown.

*Horizon and Locality.* — Niagara group; St. Paul, Ind.

### CENTROCRINUS W. and Sp.

1881. W. and Sp.; Revision Palæocr., Part II., p. 104 (Proceed. Acad. Nat. Sci. Phila., p. 278).
Syn. *Actinocrinus* (in part) Lyon; 1869, Trans. Amer. Philos. Soc., p. 453.

Dorsal cup elongate, plates smooth. Basals represented by a large pentagonal disk, showing no traces of suture lines. Radials unusually large, followed by two costals, which are proportionally very small. Distichals still smaller, taking the form of arm plates. Arm openings large, directed outward. First interbrachial plates large, followed by two smaller pieces. All other parts of the calyx unknown. Column very small.

*Distribution.* — Represented, so far as known, by a single species from the Hamilton group of America. *Centrocrinus tennesseensis* Worthen, from the Niagara group of Western Tennessee (Geol. Rep. Illinois, Vol. VIII., p. 95, Plate 14, Fig. 1), has infrabasals, and is a totally different thing.

*Remarks.* — The name *Centrocrinus* was previously proposed by the

Austins,* who recommended its application for certain species of *Platycrinus* with "central valvate unobstrusive mouths, or mouths capable of being withdrawn into the visceral cup." Even substituting "anal opening" for mouth, there is no Platycrinoid to which the above definition is applicable; besides the name has never been accepted by any writer, nor was it applied to any particular species by Austin himself. *Centrocrinus,* as here defined, is allied to the Platycrinidæ in its anchylosed large basal disk and the small size of its costals, but differs essentially in having two rows of interbrachials within the limits of the dorsal cup. Lyon's figures show interbasal sutures, but they cannot be seen in his specimens.

### **Centrocrinus pentaspinus** (Lyon).

*Plate XXV, Figs. 10a, b, c.*

1869. *Actinocrinus pentaspinus*—Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 453, Plate 26, Figs. *d* and *dl*.
1881. *Centrocrinus pentaspinus*—W. and Sp.; Revision Palæocr., Part II., p. 104 (Proceed. Acad. Nat. Sci. Phila., p. 279).
Syn. *Actinocrinus multicornus* Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 455, Plate 26, Fig. *e*; and *Centrocrinus multicornus*—W. and Sp. (Revision, Part II., p. 105).

Dorsal cup as wide as high, subcylindrical, flat below, the sides at right angles to the bottom. Plates without ornamentation, but the radials, and sometimes the first interbrachials and first costals, armed with a sharp spine, while the other plates are merely convex.

Basal disk very large, forming a regular pentagon, whose surface is covered by a sort of rounded collar, extending over the greater part of the surface, leaving only the angles free. Radials almost twice as large as the two costals together, the upper face much narrower than the lower. First costals quadrangular, half the width of the radials, and less than half their length; the second costals shorter than the first, pentagonal, with obtuse upper angle. Distichals two, short, curved like arm plates; the upper ones excavated to form the arm openings, which are large and arranged in groups with wide interspaces. Interbrachials four; the first plate large, hexagonal, rising to the top of the first costals, the lower angle deeply wedged in between the radials; the two of the second range are followed by a small piece, resting between the arm bases. Ventral disk, arms and anus unknown. Column small; axial canal apparently circular.

* Thomas Austin, and Thomas Austin, jun., 1843, Monogr. Rec. and Foss. Crin., p. 6.

*Horizon and Locality.* — Upper Helderberg group; Falls of the Ohio, near Louisville, Ky.

*Type* in the Lyon collection at Jeffersonville, Ind.

*Remarks.* — *Actinocrinus multicornus* Lyon is undoubtedly a mere variation of this species. The addition of small spinous extensions upon the first costals and first interbrachials is not a sufficient reason for specific distinction.

## DOLATOCRINUS Lyon.

1857. Lyon; Geol. Rep. Kentucky, Vol. III., p. 482.
1877. S. A. Miller; Cat. Amer. Palæoz. Foss., p. 77.
1881. W. and Sp.; Revision Palæocr., Part II., p. 124 (Proceed. Acad. Nat. Sci. Phila., p. 298).
Syn. *Cacabocrinus* — Hall; 1862, 15th Rep. N. Y. State Cab. Nat. Hist., p. 137.

Calyx depressed. Dorsal cup flattened below, sometimes to the full height of the costals; the plates generally ornamented with radiating ridges and nodes. Ventral disk but slightly elevated, surmounted by a large, almost central tube; the interambulacral spaces depressed. Basals anchylosed, the lines of union obliterated. Radials large and hexagonal. Costals two; the first quadrangular, with convex upper and lower faces, narrower than either radials or second costals, and wider than long; the upper one pentangular. Distichals two to four in species with only two primary arms; but when there are additional bifurcations in the calyx there is but one. Ambulacral openings large, arranged in groups, with wide interspaces, and directed upwards. Arms biserial, generally bifurcating. Interbrachials rather numerous, there being generally three ranges. The two proximal rows consist of a single plate each, of which the first is the largest plate of the calyx, rising to the top of the first distichals; the upper row connecting insensibly with the interambulacral plates. The latter plates consist in most of the species of a single row of from five to seven rather large cuneate pieces — the smaller end directed downward — which, except the three middle ones, are not in contact laterally throughout their full length, their lower ends being slightly excavated, so as to leave narrow slit-like openings between the plates, two to three to each side of the interradius, or four to six to the whole area. Some species have two rows of interambulacral plates instead of one, four to six smaller ones being placed beneath the others, and the upper margins of these plates are slightly pierced by the lower ends of the slits. Above the interdistichal areas, there are rarely more than two slits, and not exceeding four. In the dorsal cup, the arrangement of the interradial plates is invariably the same at all sides, but at the anal side the ventral disk has a few additional pieces, and the plates pierced by the slits are shorter. The disk contains large orals, pushed anteriorly by the stout, almost central anal tube, and it has well defined radial dome plates of a first and second order. Ambulacra subtegminal. Column large, round; the sides covered in some of the species by large angular processes or ribs; axial canal very large and pentalobate.

*Distribution.* — Restricted to the Upper Helderberg and Hamilton groups of America.

*Type* of the genus. — *Dolatocrinus lacus* Lyon.

*Remarks.* — The complete anchylosis of the basals, the large size of the first interbrachial and its being followed by a single plate, the large anal tube, and the slit-like openings at the sides of the arms, together with the perfect symmetry of the dorsal cup, form excellent characters of this genus.

Lyon described the base as composed of five pieces, while Hall mentions three basals, but the fact is that the sutures are not visible externally in the specimens. Mr. Victor Lyon, however, sent us a specimen in which the presence of three plates is indicated at the inner floor, while no suture lines appear exteriorly.

The slit-like openings have not been noticed before. We regard them as analogous to the respiratory pores of *Batocrinus*, from which, however, they differ in number, form and arrangement.

Hall, in 1862, described several species of the type of *Dolatocrinus* under *Cacabocrinus*, a catalogue name of Troost, and among them *Cacabocrinus Troosti* and *C. lamellosus*, of which we have been unable to get authentic specimens. The descriptions are too general for specific identification.

### **Dolatocrinus lacus** Lyon.

*Plate XXVI. Figs. 6a–c.*

1857. Lyon; Geol. Rep. Kentucky, Vol. III., p. 488, Plate 4, Figs. 2, 2*a–c*.
1881. W. and Sp.; Revision Palæocr., Part II., p. 126.

Calyx depressed hemispheric, flattened below, somewhat tumid around the summit. Dorsal cup more than once and a half as wide as high; the basals and the lower half of the radials deeply incurved, and formed into an inverted funnel-shaped concavity, which is wider than the column, the latter touching only the bottom part. The upper half of the radials, and nearly the whole of the first costals, spread out horizontally; while the second costals and distichals turn straight upward. The ornamentation of the dorsal cup consists of two or three rows of parallel ridges, which pass out from the middle of the plates — with or without interruption — to adjoining plates, so as to form numerous concentric triangles. A more conspicuous ridge passes up and down the rays. Another, equally prominent, connects the radials laterally, and forms a pentagon around the basal concavity. The radials, first costals and first interbrachials are each surmounted by a prominent node, while the plates of the tegmen are covered with small, granular prominences.

Basals small, almost completely concealed by the column; forming a conspicuous cone at the inner floor of the calyx. Radials larger than first and second costals together, their greatest width equal to their length; their upper lateral faces shorter than the lower. First costals once and a half as wide as long, the upper and lower faces somewhat convex. Second costals a little longer and wider than the first. Distichals $2 \times 10$ in the calyx; the lower one almost as large as the preceding axillary; the others small, and supporting the arms of which there are two to the ray. Arm bases projecting; the ambulacral openings large. First interbrachials as large as the radials and first costals together; they rise to the height of the first distichals, and are followed by a single much smaller plate in the second row, and three still smaller ones above, which support three or four plates in the disk. Orals and radial dome plates well defined, larger than the interambulacrals. Anal tube almost central. Column round; the axial canal large and pentalobate.

*Horizon and Locality.* — Hamilton group; in the limestone bed above the Black Slate; Louisville, Ky.

*Type* in the Lyon collection at Jeffersonville, Ind.

### **Dolatocrinus Marshi** Lyon.

*Plate XXVI. Figs. 1a, b, c, d.*

1869. Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 461, Plate 27, Figs. *n*, *n* 1, *n* 2.
1881. W. and Sp.; Revision Palæocr., Part II., p. 126.

Calyx of medium size, wider than high. Dorsal cup basin-shaped, the bottom deeply excavated and truncated to near the top of the second costals; the sides gently curving upward to about a vertical position; the arm bases slightly projecting and lobed, giving to the cross-section an obtusely pentagonal outline. Ventral disk low-pyramidal, the interambulacral spaces flat or slightly depressed, and the plates apparently without ornamentation. In the dorsal cup the plates are traversed by a large number of very fine radiating ridges, passing from plate to plate, four to five from each side, which are well defined near the outer margins of the plates, but become more indistinct along the median portions. Interbrachial plates a little convex, the plates of the rays from the margin of the basal concavity to the middle of the second costals surmounted by keel-like, very conspicuous protuberances, which rise from the lateral margins of the plates, at first very gradually, but near the middle of the plates almost perpendicularly, forming knife-like edges at the outer end. The ridges are continued upon the distichals, but above the costals lose their knife-like character.

Basal disk small; restricted to the lower part of the concavity, which is completely filled by the upper end of the column. Radials a little larger than the costals, their lateral sloping upper faces considerably shorter than the corresponding lower. Distichals two — sometimes three — the upper one short and lunate, supporting the primary arms, two to the ray. First interbrachial larger than any of the other plates, nearly as wide as long; followed by a good sized single plate, and this by two ranges of three plates each, which rest between the arm bases. In the tegmen there are two large cuneiform plates to each interambulacral space, which are faced by two or more smaller pieces with four slits. Two similar plates and two slits overlie the interdistichal spaces. Orals large, pushed anteriorly. Radial dome plates quite conspicuous; three of them resting within the re-entering angles of the orals, the two others against the large anal tube.

*Horizon and Locality.* — Upper Helderberg group; Falls of the Ohio, near Louisville, Ky.

*Type* in the Lyon collection, Jeffersonville, Ind.

*Remarks.* — Lyon described the basals as "horizontally disposed," and "not concealed in the pit." We conclude from his type specimen that he mistook the extended outer edges of the top stem joint for the margin of the basal disk, and its nucleus for the column. Another specimen in the Lyon collection shows the inner floor of the basal disk, which appears to be tripartite.

**Dolatocrinus Marshi,** var. **hamiltonensis** W. and Sp.

*Plate XXV. Figs. 2a, b.*

A form very similar to *D. Marshi* occurs in the Hamilton group, which we distinguish from the typical form as variety *hamiltonensis.* The basal concavity is shallower and narrower, the radial ridges knife-like, and occupy the median line of the plates instead of being keel-shaped and rising gradually from the outer margins of the plates. The ventral disk is considerably lower, and but slightly convex; the orals smaller, the posterior one, which is very short, is placed so as to form at the anterior side the base of the anal tube. All plates of the disk covered by several well defined tubercles.

*Horizon and Locality.* — Hamilton group, Bear grass quarries, Louisville, Ky.

*Type* in the collection of Mr. Victor W. Lyon, Jeffersonville, Ind.

**Dolatocrinus Lyoni** W. and Sp. (nov. spec.).

*Plate XXV. Figs. 6a, b, c, d.*

Calyx rather large, considerably wider than high. Dorsal cup more than twice as wide as high; the basal portions deeply impressed, forming a broad funnel-shaped cavity which includes one half the radials. The plates above the first costals curve gradually upwards, and the two upper rows stand at right angles to the truncated lower part of the calyx. Ventral disk low-pyramidal, slightly grooved toward the arm bases; the plates flat, covered with numerous small pustules. The plates of the dorsal cup are grotesquely ornamented with a variety of prominences and depressions; some of them elevated into sharp, very conspicuous, transversely rounded nodes, others sharply pointed; and from all of them somewhat irregular, subangular ridges pass out to the margins of the plates, connecting with similar ridges from adjoining plates. The plates of the rays have no nodes, and but few ridges proceed upwards; those directed laterally form a well defined pentagon around the basal concavity. In the upper part of the calyx the nodes cover the greater part of the plates, and the ridges are merely indicated at their outer margins.

Basals small, restricted to the bottom part of the cavity. Radials nearly as large as the two costals together. First costals quadrangular, narrower than the radials; the second pentangular, supporting upon one side an axillary distichal followed by 3 × 2 palmars and two arms, upon the other three fixed distichals, which support one arm. There are three primary arms, two and one, to the ray; two of the simple arms facing the anal interradius. Arm openings directed obliquely upwards, less projecting and smaller than usual in the genus. Interbrachials: 1, 1, 3, 4; the first large, rather angular below, broadly truncate above, the upper sides a little wider than the lower; the second almost as large as the first, with a long transverse node. The three plates of the third row much smaller and provided with elongate nodes. The plates of the fourth row, which occupy the arm regions, are small and highly convex, their upper faces pierced by the lower part of the slits. The interambulacral plates consist of five large cuneate plates, of which the three middle ones are larger than the others; the sides of the outer ones excavated to form the slits, which are quite large in this species. The anal interradius has a few additional plates in the disk, which connect with the anal tube. Interdistichals four to the arm regions, arranged in two rows, followed by three cuneate interambulacral plates, with two slits, while there are four slits above the interbrachial spaces. Orals large, all of similar form and size, surrounded by good sized radial dome plates of a first, second, and third order. Anal tube almost central, its base formed of rather large convex plates.

Three / primary
arms in each ray

*Horizon and Locality.* — Upper Helderberg group; Clark Co., Ind.

*Types* in the collection of Victor W. Lyon, Jeffersonville, Ind.

*Remarks.* — This species is readily distinguished from all others of this genus known to us by the grotesque style of its ornamentation.

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### **Dolatocrinus canadensis** Whiteaves.

*Plate XXV. Figs. 7a, b.*

1887. Whiteaves; Geol. and Nat. Hist. Surv. Canada; Contrib. to Can. Palæont., Vol. I., p. 99, Plate 12, figs. 3, 3*a*.

Of the type of *Dolatocrinus Marshi*, but with a different arm formula. Calyx small, much wider than high. Dorsal cup broadly and shallowly basin-shaped, slightly depressed along the radials, and more conspicuously at the basals. Ventral disk lower than the dorsal cup; hemispherical; the central portions slightly tumid. The ornamentation of the dorsal cup consists of numerous parallel ridges, passing out to the sides of the plates, and meeting those of adjoining ones. The rays along their median lines followed by broad, keel-like processes, which form into a knot in the centre of the radials and second costals. Another prominent ridge runs from the lower margins of the first interbrachials to the middle of the plates, where it forms a rather sharp node, from which two branches proceed to the upper lateral margins. The smaller ridges, of which there are three to four to each side, are marginal, extending but a short distance into the plates.

Basals small, perfectly anchylosed, surrounded by a circular ridge, and entirely covered by the column. Radials larger than the costals, hexagonal, wider than long, widest above the middle and not visible from a side view. First costals short, quadrangular; the second considerably wider, a little longer and axillary, giving off to one side an axillary distichal, which supports a small palmar at each side, and this an arm. The opposite distichal gives off a single arm from the second plate, thus making three primary arms to the ray. Arm bases projecting, giving to the calyx, as seen from above, a pentagonal outline. Structure of the arms unknown. Interbrachials: 1, 1, 3; the first large; the second much wider than high; the middle plate of the third row comparatively large; the two at the sides as long, but narrower. Ventral disk composed of but few large plates, which are covered with several minute pustules of irregular arrangement; the interambulacral spaces depressed, consisting generally of only two plates, which abut against the orals. There are no interdistichals. Orals and ambulacral plates arranged as in the preceding species. Anus subcentral.

Three primary arms to each ray.

*Horizon and Locality.* — Hamilton group; near Thedford, Ontario.

*Type* in the Canada Survey Museum at Ottawa.

*Remarks.* — It is barely possible that Hall's *Cacabocrinus Troosti*, from Western New York, is identical with this species, but it is described with four primary arms instead of three.

### **Dolatocrinus triadactylus** Barris.

*Plate XXVI. Figs 4a–d.*

1884. Barris; Proceed. Davenp. Acad. Nat. Sciences, Vol. IV., Plate 2, figs. 5–7.
1885. W. and Sp.; Revision Palæocr., Part III., p. 105.

Of medium size. Calyx depressed, a little wider than high. Dorsal cup broadly basin-shaped; the lower portions truncate to near the top of the first costals, then curving rapidly upwards, a little constricted below the arm bases; the basals moderately excavated, and the margin of the cavity surrounded by a circular ridge; the arm bases slightly projecting. Surface covered by numerous angular ridges, which radiate from centre to centre of the plates, producing various geometrical figures. The ridges connecting the radials form a pentagon around the basal pit, which is radially disposed and of which the sides support five triangles, each one enclosing a smaller one. The outer triangles, together with the pentagon, form a five-rayed star, and the spaces between the rays of this star are also formed into triangles, which are followed by other triangles above.

Basals small, resting completely within the columnar depression. Radials and costals of equal height, but the first costal narrower than the second. The latter supports at one side an axillary distichal, followed by two small palmars and two arms, and at the opposite side by two successive distichals and a single arm, making three arms to the ray. Arms stout, biserial, not bifurcating at the lower ends; their upper parts unknown. Arm joints short, with parallel faces. First interbrachial large, supporting a smaller, subquadrangular plate, and three plates in the third row, which in turn are followed by five cuneate plates, which extend above the level of the arm regions. At the four regular sides, the three middle ones of these plates are considerably larger than the outer ones, and touch the orals; at the anal side they are followed by a few additional plates, which abut against the anal tube. Interdistichals small, consisting of three pieces, succeeded by two interambulacral plates forming two slits. The number of slits at the interradial spaces cannot be ascertained from the specimens. Ventral disk slightly tumid; the interambulacral spaces depressed, the plates almost flat, the orals and radial dome plates, which are somewhat larger, covered with small but sharp nodes. Anus subcentral. Column round, with crenulated edges; axillary canal pentangular.

*Horizon and Locality.* — Hamilton group; Alpena, Mich.

*Types* in the Museum of the Davenport Academy of Sciences.

### **Dolatocrinus glyptus** (Hall).

*Plate XXVI. Figs. 2a, b.*

1862. *Cacabocrinus glyptus* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist., p. 140.
1881. *Dolatocrinus glyptus* — W. and Sp.; Revision Palæocr., Part II., p. 125.
Syn. *Cacabocrinus glyptus*, var. *intermedius* Hall; 1881, 15th Reg. Rep. N. Y. State Cab. Nat. Hist., p. 141.
Syn. *Dolatocrinus ornatus* Meek; 1871, Proceed. Acad. Nat. Sci. Phila., p. 57.

Larger than any of the preceding species. Calyx depressed-globose, somewhat flattened to near the top of the radials; rapidly curving above, so that the walls of the dorsal cup near the arm bases are parallel to those of the opposite side. Plates ornamented by interrupted ridges or lines of small nodes, some of them radiating to the angles of the plates, others to the sides; those passing from the basal pit to the arm bases the strongest and almost continuous, rising to angular nodes in the centre of each plate. First interbrachial provided with a strong central tubercle, and the ridges proceeding from the radials to the first distichals more prominent than the others. Suture lines slightly channeled.

Basal disk comparatively large, the upper angles projecting beyond the column, the median portions concave, and the cavity surrounded by a circular rim. Radials considerably wider than the costals, and also wider than long. First costals twice as wide as long, the lower faces distinctly convex, the upper a little concave. Second costals longer than the first, slightly increasing in width upwards, the sloping upper faces obtusely angular. Distichals $2 \times 2$; the first equal to two thirds the size of the axillary costal; the two of the second row not more than half the size of the first, and those of the second row separated by an interdistichal. Palmars two, short, lunate, supporting the two primary arms. First interbrachial almost as large as any two other plates of the calyx, and nearly as wide as long; followed by a comparatively large hexagonal plate, which supports three others; the two at the sides elongate and smaller than the middle one. Ventral disk depressed-pyramidal. Anal tube subcentral, rising gradually from the disk.

*Horizon and Locality.* — Hamilton group; near Pavilion, Genessee Co., N. Y., and Columbus, O.

*Type* in the American Museum of Natural History, New York.

*Remarks.* — We regard *Cacabocrinus glyptus*, var. *intermedius*, described by Hall, and *Dolatocrinus ornatus* Meek, as mere variations of *D. glyptus*, the specimens only differing a little in the ornamentation. In the typical *D. glyptus*, the ridges upon the plates are not continuous, but consist of irregular series of elongate nodes; while in the specimens of *D. glyptus*, var. *intermedius* they are generally not interrupted. *D. ornatus* was described by Meek as coming from the Hamilton group of New York.

**Dolatocrinus liratus** (Hall).

*Plate XXVI. Fig. 3.*

1862. *Cacabocrinus liratus* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist, p. 139.
1881. *Dolatocrinus liratus* — W. and Sp.; Revision Palæocr., Part II., p. 126.
Syn. *Cacabocrinus liratus*, var. *multilira* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist., p. 139.

Very closely resembling *D. glyptus*, and probably a mere variety of that species. The specimens referred to the latter by Hall are shorter and their basal portions more depressed, but this may possibly be due to pressure. They agree in the form and arrangement of the plates, and both have two primary arms to the ray, a depressed ventral disk, ridges along the ambulacra, and an almost central anal tube. The only perceptible difference is in the style of ornamentation. The ridges, which in *D. glyptus* are more or less interrupted, are continuous in *D. liratus*. It has, besides, large ridges radiating from the centre of the plates to each of their angles, and three to five smaller ridges passing out to the sides, where they join with similar ridges from adjacent plates. The plates of the ventral disk are densely crowded with large and small prominences, similar to those found in certain species of *Amphoracrinus*.

*Horizon and Locality.* — The same as the preceding species.

*Type* in the New York State Cabinet of Natural History at Albany.

**Dolatocrinus icosidactylus** W. and Sp. (nov. spec.).

*Plate XXVI. Figs. 5a–d.*

A large and greatly depressed species of the type of *D. glyptus*, but readily distinguished by having four instead of two primary arms to the ray. When not crushed, the calyx to the base of the anal tube only about four fifths as high as wide, but it appears to be still shorter in the usual preservation. Dorsal cup twice as high as the tegmen, broadly cup-shaped, flattened to the top of the costals, and the basals formed into a funnel-shaped cavity, surrounded by a circular ridge. The median lines along the plates of the rays to the bases of the arms elevated into prominent ridges, and the middle of each radial and costal crowned by a small central node. The nodes are directed longitudinally; they are in some specimens quite conspicuous, while the ridges are almost obsolete; in others, however, the ridges are almost as high as the nodes. Smaller ridges, or more properly speaking, rows of elongate nodes, radiate from near the middle of the radials and costals to the larger interbrachials, the latter having generally four such ridges to each side of the plate, arranged parallel. Toward the upper part of the dorsal cup the ridges almost disappear, and the plates are simply tumid.

Basal disk depressed funnel-shaped; the outer rim on a level with the radials; perforated by a large, pentalobate canal with sharp re-entering angles, which extend deeply inward. Radials larger than the costals, their length equal to the width at the lower end; the truncated upper faces concave; the sloping upper faces much shorter than the sloping lower. First costals subquadrangular, narrower than the radials; upper and lower sides convex. Second costals very little wider, but considerably longer and pentangular. Distichals $1 \times 10$; all axillary; almost as large as the second costals. Palmars much smaller, the two lower ones, which are short and lunate, incorporated into the calyx. Arm openings arranged in groups; large; directed obliquely upwards. Primary arms twenty. Interbrachial spaces wide, the plates arranged: 1, 1, 2; the first larger than the radials; the second almost as large as the first costals, subquadrangular; the two of the third row much smaller. Between the arm openings are three to five minute pieces, which are followed by two large elongate plates in the tegmen, and several additional plates at the anal side. There are four slits to each interradial space, and the same number to each interdistichal space. Ventral disk low-hemispherical, surmounted by a medium sized almost central tube; the course of the ambulacra marked by an elevation, the interambulacral spaces depressed, especially near the outer margin; the plates completely covered with small pustules of even size. Orals and ambulacral plates as usual in the genus. Column round, the joints with slightly waving edges, and rapidly increasing in size downwards; the nodal joints projecting.

*Horizon and Locality.* — Hamilton group; Louisville, Ky.

*Types* in the collection of Wachsmuth and Springer, and Victor W. Lyon.

*Remarks.* — This species bears some resemblance to "*Cacabocrinus*" *lamellosus* Hall; but differs considerably in the form and size of the basal depression, which in the latter species, according to Hall, is large, subcircular, and embraces the basals and one third of the radial plates. It also occurs at a different geological horizon.

**Dolatocrinus excavatus** W. and Sp. (nov. spec.).

*Plate XXV. Fig. 1,* and *Plate XXVI. Figs. 7 and 8.*

A very large species. Dorsal cup shallow-basin shaped, three times as wide as high; the bottom flattened to the top of the costals; the sides convex, rapidly curving upwards, a little constricted at the arm bases; the radials formed into a deep, sharply pentangular, funnel-shaped pit, which penetrates the calyx almost to the height of the arm regions. Surface of plates — except those in the pit — covered with parallel ridges, radiating from the centre of the plates to their sides, where they meet with similar ridges from adjoining plates. In addition to these ridges there are keel-like projections following the radials and costals, which grow more conspicuous downward, and at about the top of the radials are produced into a tubercle, which projects into the funnel-shaped pit, and gives its upper margin a slightly stellate outline. Occasionally the carinate ridges are continued to the higher brachials, but, as a rule, they become obsolete above the second costals. Suture lines slightly grooved.

Basals elongate; forming together with the radials a highly elevated inverted cone with a large pentalobate canal. Radials large, once and a half as long as wide; four fifths of the plates taking part in the pit, the other fifth bending abruptly outward; upper sloping faces short; the lower faces equal to one half the greatest width of the plates. First costals small, twice as wide as long, their upper and lower faces convex. Second costals wider than long and slightly wider than the first. Distichals four; the first as large as the two costals together. Arms two to the ray, about equidistant. First interbrachial slightly curving, larger than the radials and first costals together, elongate, widest across the middle of the plate; angular at both ends; the lower end bending inward so as to form a part of the pit. There are two large plates in the second row, three smaller ones in the third, and these are succeeded by a row of six elongate pieces in the ventral disk, and two additional larger plates which abut against the orals. Interdistichals one or two in the dorsal cup, followed by five or six small pieces in the tegmen, and a larger one between the secondary radial dome plates. Slits six to each interradial space, and four to each interdistichal one. Ventral disk depressed, slightly tumid; the interambulacral spaces flattened, and sometimes a little depressed, producing indistinct ridges along the ambulacra.

Orals large; the posterior one small and lunate, owing to the almost central position of the large anal tube.

*Horizon and Locality.* — Upper Helderberg; Clark Co., Ind.

*Types* in the collection of Victor W. Lyon.

*Remarks.* — Differing from all other known species of this genus in the great size of the calyx, the form and depth of the basal pit, in having two secondary interbrachials, and in the number of the slits. The specimen on Plate XXVI., Fig. 7, exhibiting the inner floor of the disk, is very interesting as showing the communication of the slits with the inner cavity.

### **Dolatocrinus major** W. and Sp. (nov. spec.).

*Plate XXV. Fig. 5.*

A very large species, in general form resembling the preceding, but with a shallow basal depression, four arms to the ray, and without surface ornamentation. Dorsal cup depressed-bowl-shaped, almost three times as wide as high, flattened below; the radials and part of the costals stretched out horizontally; the basals forming a shallow concavity surrounded by a thickened rim; the sides gently bending upwards and becoming parallel at the top of the first distichals. The plates are smooth, with the exception of a small rounded node upon the two costals; that of the first costal occupying the upper end of the plate, that of the second the median part. Radials comparatively small, considerably wider than long; the upper and lower lateral faces almost equal; the lower margin thickened and forming a rim around the basal concavity. First costal as large as the radials; the upper face decidedly convex, and the lateral ones slightly, but the lower face straight. Second costal larger than the first, broadly pentangular. Distichals $1 \times 10$; large; axillary; supporting two good sized fixed palmars, and these the free arms. Arms twenty, arranged at almost equal distances around the calyx. Interbrachial spaces somewhat depressed at their lower ends, and slightly receding between the arm bases; the first plate large, its upper half considerably wider than the lower half, its upper face truncate and somewhat concave. The plate of the second row is approximately as large as the first costals, but higher than wide and hexagonal; the lower lateral faces parallel, the upper lateral ones sloping. There are three plates in the third row, and others above. Interdistichals one. Structure of the ventral disk unknown.

*Horizon and Locality.* — Upper Helderberg group; Falls of the Ohio.

*Type* in the collection of Victor W. Lyon.

## **Dolatocrinus speciosus** (Hall).

*Plate XXV. Figs. 4a, b.*

1862. *Cacabocrinus speciosus* — Hall; 15th Rep. N. Y. State Cab. Nat. Hist., p. 137.
1881. *Dolatocrinus speciosus* — W. and Sp.; Revision Palæocr., p. 126.

Of the type of *D. major*, but smaller; the dorsal cup proportionally higher, and provided with a somewhat deeper basal pit; the radials instead of being stretched out horizontally, gradually slope toward the basal concavity, without actually forming a part of it. It has but two distichals, and two arms to the ray instead of four; arranged in pairs with wide interspaces. Cross-section below the arm regions subpentangular. Plates apparently without ornamentation, their surfaces slightly convex; the median line of the plates following the rays gradually rising into a keel-like projection or carina, which passes up to the bases of the arms. This carina is higher upon the radials and costals, and thickened at the middle of each plate, where it is formed into a conspicuous elongate node; the node of the first costals more prominent than the others.

Basals small, forming a shallow inverted basin, which is completely filled by the column. Radials larger than the costals, and about as wide as long. The first costal narrower and shorter than the second, and quadrangular; the second obtusely angular above. Distichals 2 × 10, comparatively large; followed by a lunate arm plate. Arm openings two to the ray, directed obliquely upwards, and those of the same ray packed closely together. First interbrachial almost as wide as long, with an obtuse lower angle, and its upper face broadly truncated; the second about half the size of the first, its lateral faces parallel. The latter supports three plates, two upon its sloping lateral sides, and one upon the truncated upper face, which are followed by a row of interambulacral pieces. The interdistichal spaces contain two plates. Ventral disk slightly convex, each side containing four interambulacral plates, two of them larger and cuneate, touching the orals, the two smaller ones abutting against the secondary radial dome plates. The posterior oral is deeply wedged in between the four others, and considerably shorter. Anus almost central.

*Horizon and Locality.* — Upper Helderberg group; Western New York.

The specimen figured is from the collection of Wachsmuth and Springer.

1 to
each ray.

**Dolatocrinus tuberculatus** W. and Sp. (nov. spec.).

*Plate XXV. Fig. 3.*

Of the type of *D. glyptus* Hall, but differing in the style of ornamentation. Dorsal cup not twice as wide as high; subglobose, slightly depressed from the middle of the radials downward; central concavity small, elliptical, formed by the basals only, and completely filled by the upper column joints. The radials, costals and first interbrachials are each elevated into a large, very conspicuous tubercle, and the tubercles are connected by well-marked ridges. There are generally four parallel ridges from the interradial to the radial nodes, and the same number between the radials and first costals, which form five sets of four triangles around the column at some distance from it; those of the same set concentric. The costals are connected with the first interbrachial by two ridges, while there is but one ridge, but more prominent, between the distichals. Other ridges connect the distichals with the higher interbrachials. Basal disk small, almost completely hidden by the column, and surrounded by a prominent circular rim with small nodes interradially disposed. Radials large, almost as long as wide, much larger than the first costals; the second costals higher and wider than the first. Distichals apparently two, each one provided with a short node. First interbrachial smaller than usual in this genus; followed by a quadrangular plate in the second row, and three smaller plates above. Nothing is known of ventral disk and arms.

*Horizon and Locality.* — Hamilton group; Clark Co., Ind.

*Type* in the collection of Mr. Victor W. Lyon.

## STEREOCRINUS Barris.

1878. Barris; Proceed. Davenport Acad. Nat. Sciences, Vol. II., p. 282.
1881. W. and Sp.; Revision Palæocr. Part II., p. 126 (Proceed. Acad. Nat. Sciences, Phila., p. 300).
1885. Barris; Proceed. Davenport Acad. Nat. Sciences, Vol. IV., p. 103.
1889. S. A Miller; North Amer. Geol. and Palæont., p. 283.

In general form, ornamentation, and the arrangement of plates resembling *Dolatocrinus,* but having one costal instead of two, and a tripartite base. Dorsal cup depressed, truncate below. Basal disk small, pentagonal; composed of three pieces, of which the suture lines are generally visible. Radials and costals nearly of equal size; the former hexagonal, the latter pentagonal and axillary. Distichals two or three, supporting the arms.

Arm openings, so far as observed, two to the ray; arms biserial. Interradial spaces wide, containing three ranges of plates in the dorsal cup; the first and second range composed of one plate each; the third of two or three; followed by large cuneate plates in the disk. Ventral disk rather flat, the interambulacral spaces depressed, containing one or more slit-like openings at each side of the arms. Ambulacra subtegminal, but their course indicated by elevations upon the disk. Orals large and arranged as in *Dolatocrinus*. Anus subcentral, apparently at the upper end of a tube. Column round; central canal large and pentalobate.

*Distribution.* -- This genus has been observed only in Michigan and Iowa. The typical species came from the Hamilton group; but we have in our collection a specimen apparently of another species, from rocks considered to be Upper Helderberg, of Waterloo, Iowa; it is not, however, sufficiently perfect for description.

### Stereocrinus triangulatus Barris.

*Plate XXV. Figs. 8a, b.*

1878. Barris; Proceed. Davenport Acad. Nat. Sciences, Vol. II., p. 261, Plate 11, Figs. 1, 2.
1881. W. and Sp.; Revision Palæocr., Part II., p. 127.

A rather large species. Dorsal cup shallow-basin shaped, twice as wide as high; the truncate lower part formed by the basals, radials, the larger half of the costals, and a large part of the first interbrachials; the lateral walls of opposite sides nearly parallel; the extreme upper end slightly constricted, and the interradial spaces a little depressed between the arm bases. Ornamentation resembling that of *Dolatocrinus triadactylus*, the surface being covered by similar sets of parallel ridges, but less prominent. Only one of each set passes from centre to centre of the plates, the others being interrupted. By means of these ridges the whole surface of the dorsal cup is divided up into numerous triangles, each one enclosing one or two smaller ones. There are five such sets of triangles around the basals, three to each set, and similar triangles are formed in the upper part of the calyx.

Basals largely projecting beyond the column; central canal large, pentalobate. Radials a little larger than the costals, all wider than long. Distichals $2 \times 10$; the first rather large; the second short, lunate. Arm bases projecting, arranged in pairs. Arms two to the ray; their structure unknown. First interbrachial a little larger than the radials; the second about half the size of the first, followed by two or three plates in the third row, and a number of small plates in the ventral disk. Disk depressed-hemispheric; the interambulacral spaces nearly on a level with the ambulacra; all the plates slightly convex. Anal tube large at the base, and almost central.

*Horizon and Locality.* — Hamilton group; Davenport, Iowa.

*Types* in the Museum of the Davenport Academy of Sciences.

*Remarks.* — The small specimen which Barris described as variety "*liratus*," is in our opinion not sufficiently distinct for separation, and, it seems to us, the differences given are readily explained by individual growth.

**Stereocrinus Barrisi** W. and Sr. (nov. spec.).

*Plate XXV. Figs. 9a, b.*

Syn. *Stereocrinus triangulatus* Barris (in part).

Of medium size. Calyx more than once and a half as wide as high, flattened to the top of the radials, and slightly depressed at the basals; the sides from the middle of the costals rising vertically; lobed at the arm bases. Ventral disk short, slightly tumid, the interambulacral spaces deeply depressed so that the ambulacral regions are conspicuously elevated. Plates of the dorsal cup covered by similar sets of triangles as in the preceding species, but the ridges forming them more prominent, and there is a node in the centre of each plate; suture lines difficult to see. The column is surrounded by a strong circular ridge.

Basal disk projecting beyond the column. Radials and costals nearly equal in size, the former hexagonal, the others heptagonal. Distichals three in the calyx; the first a third the size of the costals; the second and third extremely short, the latter facing laterally. First interbrachial very large, the two of the second row much smaller. Ambulacral openings large, elongate. Respiratory pores four to each interradius, and two above the interdistichal spaces. Orals rather large, slightly tumid, pushed to the anterior; the posterior one resting against the base of the anal tube, which is almost central. The plates covering the food grooves small and tuberculiform; the interambulacral ones somewhat larger and almost flat. Column small, round; the axial canal large and pentalobate.

*Horizon and Locality.* — Hamilton group; Alpena, Mich.

*Types* in the Museum of the Davenport Academy of Sciences, and in the collection of Wachsmuth and Springer.

*Remarks.* — This species has close affinities with the preceding one, and

Barris apparently regarded the two forms as representing the same species. However, on examining a large number of specimens of both types, we find a separation necessary. In *S. Barrisi* the basal disk is small, extending but slightly beyond the column, and the facet for the reception of the column is surrounded by a heavy, circular rim. In *S. triangulatus* the disk is quite large, the top stem joint occupying less than half its diameter, and it has no rim around the facet. The interambulacral spaces of *S. Barrisi* are much more depressed, the ambulacra more abruptly protruding, the orals larger, and the interambulacral plates flat and less numerous.

## HADROCRINUS Lyon.

1869. Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 445.
1881. W. and Sp.; Proceed. Acad. Nat. Sci. Phila., p. 396 (Revision, Part II., p. 222).
1889. S. A. Miller; N. A. Geol. and Palæont., p. 252.

Calyx very large; the dorsal cup saucer-shaped, its lower portions concave. Basals small, completely covered by the column and placed at the bottom of the cavity; they are closely anchylosed, and their suture lines are visible only upon the inner floor. Radials pentangular, the lower half bent inward, the upper stretched outward. Costals one, pentagonal. Distichals and palmars are always represented in the calyx, and sometimes post-palmars; each order by two to four successive plates of the same size as the costals; the uppermost plate excavated to form a facet, which is directed laterally, and supports the arms. Interbrachials variable in number and irregular in their arrangement, as large as the adjoining brachials. The anal side may, or may not have an additional plate in the second row. Interdistichals one to three, longitudinally arranged, as large as the interbrachials. Structure of ventral disk, arms and anus unknown. Column very large near the calyx (Lyon), round, tapering rapidly, and giving off cirri; axial canal circular at the top of the column, but pentalobate farther down.

*Distribution.* — Only known from the Upper Helderberg group.

*Type* of the genus. — *Hadrocrinus discus* Lyon.

*Remarks.* — The specimens are all imperfect, and no satisfactory definition of the genus can be given. It is allied to *Stereocrinus* in having but one costal to the ray, but differs essentially in the number and arrangement of the interbrachials, and in having sometimes an anal plate. Lyon's description of the column needs confirmation, being made from detached pieces. His *H. pentagonus* is defined from a single ring of plates, and the species cannot be recognized.

### Hadrocrinus discus Lyon.

*Plate XXIV., Fig. 1.*

1869. Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 448, Plate 26, fig. *a*.
1881. W. and Sp.; Revision Palæocr., Part II., p. 222.

A very large species. Dorsal cup flat-saucer-shaped, the radials forming a shallow concavity, of which the basals occupy the bottom, the radials the sides. From the top of the radials to the second distichals the plates are directed horizontally, and from there they proceed slightly upward to near the arm bases, where they attain again a horizontal position. Plates moderately heavy, apparently without ornamentation; slightly concave, the median space having a shallow circular pit, sometimes two being placed close together. Basals not visible in the specimens, and judging from the space assigned to them, they were unusually small. Radials and costals small in proportion; the former a little the larger, their lower faces one half the width of the upper; the upper sloping faces larger than the corresponding lower ones. Second costals almost regularly pentagonal. Distichals $2 \times 10$, larger than the radials, considerably longer than wide; the first hexagonal, the second pentagonal and axillary. Palmars $4 \times 20$ in the calyx, the two lower ones as large as the distichals and of a similar form, the two upper much shorter and slightly curved for the reception of the arms. Interbrachials nine or more, irregularly arranged, all nearly equal and as large as the distichals. The anal interradius has three plates in the second row, which are narrower than the two of the other sides. Interdistichals three, longitudinally arranged, elongate, hexagonal, as large as adjoining brachials. Structure of arms and ventral disk unknown. Columnar facet large, beautifully striated.

*Horizon and Locality.* — Upper Helderberg group; Falls of the Ohio, near Louisville, Ky.

*Types* in the Lyon collection.

### Hadrocrinus plenissimus Lyon.

*Plate XXIV., Figs. 2a, b.*

1869. Lyon; Trans. Amer. Philos. Soc., Vol. XIII., p. 445, Plate 26, Figs. *b* 1-3.
1881. W. and Sp.; Revision Palæocr., Part II., p. 222.

The specimens are fragmentary and crushed, so as to leave some doubt as to the actual form and size of the calyx, except that it was depressed and extremely large. Lower portions of the dorsal cup to the top of the costals deeply concave, forming a large inverted cup, which extends deeply into the cavity of the calyx; the succeeding plates spreading almost horizontally with a slight upward curvature. The entire surface covered with somewhat flattened ridges passing from near the centre of the plates to their sides, where they meet the ridges of adjoining plates. There are from two to four ridges to each side, but two of them are frequently united in the specimens, so as to form one larger ridge with a broader surface.

Basals closely united, forming a small inverted cone, which occupies the bottom of the dorsal cavity and is completely hidden by the column. The inner or ventral surface of the basals is convex, decidedly wider than the outer or dorsal surface, and marked by five well defined angular ridges, radial in position, from which small protuberances pass out and enter the axial canal, producing the pentalobate outline. Between these ridges and around the axial canal, there are five shallow circular depressions occupying two thirds of the basals, which probably lodged the quinquelocular or dorsal organ. Radials large, somewhat variable in size, about as wide as long; the lower faces wider than the upper; the upper sloping faces less than one half the length of the lower ones. Costals pentangular, very much smaller than the radials, sometimes barely one third their size. First interbrachial rising to the top of the costals, the two of the second row elongate and but little smaller; they are followed by other rows, but their arrangement, as well as that of the higher brachials, cannot be accurately determined from the specimens.

*Horizon and Locality.* — Upper Helderberg group; near Jeffersonville, Ind.

*Types* in the Lyon collection.

*Remarks.* — Lyon describes this species as having 2 × 2 "secondary radials," and several more "orders of radials" above, each order represented by two plates, and he mentions seven to eight "interradials" and two "interaxillaries." He also suggested from small detached pieces, which may possibly belong to a very different form, that this species had from eighty to one hundred arms; all of which has yet to be confirmed by more perfect specimens.

# CALYPTOCRINIDÆ.

Monocyclic. Lower brachials and interbrachials forming an important part of the dorsal cup. Radials in contact all around. Arms resting in compartments, formed by partitions attached to the tegmen. Plates of the calyx limited to a definite number. Dorsal cup, except the base, perfectly pentamerous.

*Analysis of the Genera.*

**Basals 4.**

1. *Partitions extending to the tips of the arms* . . . . . . . . . Eucalyptocrinus.
2. *Partitions enclosing only the lower portions of the arms* . . . . . . Callicrinus.

*Geological and Geographical Distribution.*

**Number of known species.**

(Open figures indicate American ; those marked ( ), European.)

| Formation. | | | Calyptocrinidæ. | |
|---|---|---|---|---|
| General. | American. | Approximate European Equivalents. | Eucalyptocrinus. | Callicrinus. |
| Devonian. | | Eifel. | (1) | |
| Upper Silurian. | Niagara. | Wenlock. Gotland. | 17 (10) | 4 (8) |
| Total species 40 $\left\{ \begin{matrix} 21 \\ (19) \end{matrix} \right.$ | | | 17 (11) | 4 (8) |

*Remarks.* — Roemer proposed the family name "Eucalyptocrinidæ" (Lethæa Geognos. (Ausg. 3), 1855, p. 229), which Angelin in 1878 changed to Calyptocrinidæ. The latter name was accepted by Zittel, who erroneously included with it *Lyriocrinus* Hall, which is a dicyclic Crinoid.

The Calyptocrinidæ agree substantially with the Dolatocrinites section of the Melocrinidæ in the construction of the dorsal cup, but their basals occupy the bottom of a deep concavity, and they are remarkable for having the

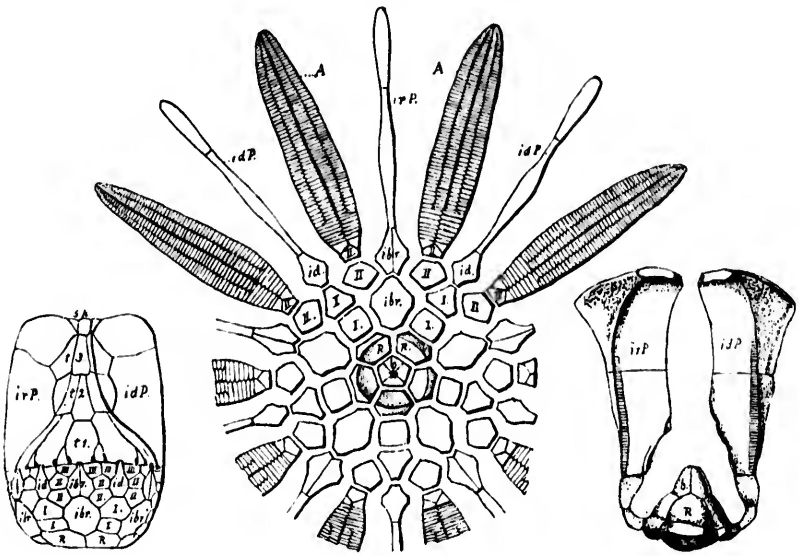


Fig. 15. Fig. 14. Fig. 16.

Fig. 14, showing plates of the dorsal cup, the arms and their partitions.
Fig. 15, the calyx in a side view.
Fig. 16, the partition walls of *Eucalyptocrinus rosaceus* (after Schultze).

$b$ = basals; $R$ = Radials; $I$ = costals; $II$ = distichals; $ibr$ = interbrachials; $id$ = interdistichals $A$ = arms; $irP$ = interradial partitions; $idP$ = interdistichal partitions; $t1$ = first ring of plates of the tegmen; $t2$ = the second ring; $t3$ = the third ring; and $t4$ = the fourth or upper ring of the tegmen.

plates limited to a certain number. The dorsal cup is perfectly pentamerous, the rays being separated by interbrachials of uniform number and size, and their main divisions by a single large interdistichal. Still more important from a classificatory point of view is the structure of the ventral disk, which differs from that of any other known Crinoid, recent or fossil. It is composed of only four rings of large plates of irregular form, of which the two lower ones completely cover the disk ambulacra, which are subtegminal, the upper ones forming a long neck or tube enclosing a narrow canal. Not only do the plates of the disk, like those of the dorsal cup, consist of a definite number, but they are throughout this family unusually large, and their arrangement does not appear to be in accordance with the pentamerous symmetry of the Crinoids generally. Another most remarkable feature, which separates this family distinctly from all other Camerata, is the compartments enclosing the arms, which are formed by processes or partitions attached to the outer sides of the disk, and are supported by the interbrachials and interdistichals.

The family was restricted to the Upper Silurian, with the exception of a single species found in the lower Devonian of the Eifel. It was the leading family of its epoch in the number of species discovered, there being twenty-one from America, and eighteen from England and Sweden, but only two genera.

## EUCALYPTOCRINUS Goldf.

1826. Goldfuss; Petref. German., Vol. I., p. 214, and 1838, Nova Acta Leop. Vol. XIX., 1, p. 335.
1841. Müller; Berl. Akad. d. Wissensch., p. 210.
1841. Hall; Palæont. N. York, Vol. II., p. 207.
1843. Roemer; Rhein. Uebergangsgeb., p. 62, and 1855, Lethaea Geogn. (Ausg. 3), p. 257, and 1860, Silur. Fauna West. Tenn., p. 48.
1853. De Koninck and Lehon; Recher. sur les Crinoides du Terr. Carbonifère de la Belgique, p. 74, with diagram.
1857. Pictet; Traité de Paléontologie, Vol. IV., p. 307.
1862. Dujardin and Hupé; Hist. Nat. des Zooph. Echin., p. 115.
1863. Hall; Trans. Albany Inst., Vol. IV., p. 197.
1866. Schultze; Monogr. Echin. Eifl. Kalk., p. 90.
1878. Angelin; Iconogr. Crin. Suec., p. 16.
1879. Hall; 28th Rep. New York State Mus. Nat. Hist., (Ed. II.), p. 141.
1879. Zittel; Handb. der Palæontologie, Vol. I., p. 379.
1885. Quenstedt; Handb. d. Petrefactenkunde (Ausg. 3), p. 963.
1885. W. and Sp.; Revision Palæocr., Part III., p. 127 (Proceed. Acad. Nat. Sci. Phila., p. 349).
1889. S. A. Miller; N. Amer. Geol. and Palæont., p. 243.
Syn. *Hypanthocrinus* Phillips, 1839; Murchison's Silur. System, p. 672, Plate 17, Fig. 3; Zittel, 1879; Angelin, 1878; S. A. Miller, 1880.

Calyx with the arms attached more or less ovate; without the arms resembling a wine bottle with concave bottom and slender neck; the neck surrounded by ten longitudinal partitions closed from above, and forming ten niches or compartments into which the arms, in pairs, and to their full length, exactly fit. Dorsal cup composed of four basals, five radials, $2 \times 5$ costals, $2 \times 10$ distichals, $1 \times 20$ palmars, $3 \times 5$ interbrachials, and $1 \times 5$ interdistichals. The basals, which form an inverted funnel-shaped cup, are not visible from a side view, and the calyx rests upon the edges of the inflected lower portions of the radials; the plates varying in size, the anterior one larger than the rest. Axial canal five-rayed, the anterior basal pierced by two of its rays. First costals quadrangular, the second pentangular unless the upper angle is truncated by the interdistichal. First distichals larger than the second. The first palmars support the arms; they are short, truncated at the upper face, and are provided with small muscle plates and fossæ. First interbrachials generally the largest plates of the dorsal cup, more than twice as large as the two above. The two latter are of about the same form and size, and are in contact laterally to their full length. They rise some distance beyond the top of the palmars in square or tapering truncate projections, and jointly form a support for the interradial partitions. The interdistichals rest either within notches formed by the distichals, or upon the truncate upper face of the second costals. They resemble in form the combined upper interbrachials, rise like these to the height of the third arm plates, and support in a similar manner to the interbrachials a partition wall upon their truncate upper faces. The projections between the arm sockets give to the specimens a very marked aspect, and serve as a reliable guide for generic identification in case the ventral structures of the calyx are not preserved; in that condition they look like cogs of a wheel.

The tegmen, or part above the dorsal cup, consists of four rings of plates of peculiar structure. The lower ring is composed of five elongate interradial pieces which rest upon the projecting upper faces of the interbrachials, and five plates of similar form and size supported by the interdistichals. The middle portions of the ten plates extend outward and upward in form of knife-like winged processes, of which the upper end rises to near the fourth row of plates, overlapping the plates of the second and third rows, to the outer faces of which they are attached by suture. Interposed between these plates are ten small trigonal pieces, arranged in such a manner that a plate supported by an interbrachial, and one supported by an interdistichal, always meet laterally over the top of one of the triangular pieces. The latter plates, which are somewhat thickened at their median lines, form a sort of subpartitions between the arms of the various pairs, without being visible when the arms are intact. Their edges at both sides, and also those of the larger plates, are pierced by the ambulacral or arm openings, which are well defined in this genus, and enter the calyx between the two plates. The second and third rings, which form the tubular prolongation of the calyx, are composed of four plates each; the fourth ring consists of ten pieces, which meet around the summit. The plates of the second ring slope upwards; two of them are wider, and alternate with the other two; the two narrower plates are longer, and angular at the top, the others truncate. United they form an inverted funnel, the margin surrounded by ten protuberances, which represent ten longitudinal ridges upon the outer surface. The ridges meet the upward prolongations of the plates of the first ring, with which they are suturally connected and form a solid wall; while the alternate grooves form the inner part of the niches. The plates of the third ring are narrower than those of the second, and like them provided with ten longitudinal elevations, which are overlapped by certain projections passing down from the plates of the fourth ring. The plates of the upper ring are quite remarkable as forming the upper part of the anal tube, the top of the crown, and at the same time the encasement for the tips of the arms. They are constructed upon a plan similar to that of the large plates of the first ring, and, like them, have wing-like extensions, which from a ventral aspect present a well defined decagonal star, with a vacant space at the summit. The lower ends of these wings meet the upper ends of the wings of the first ring, so as to form, together with the projecting surfaces upon the plates of the two middle rings, ten continuous walls, which extend from the edges of the dorsal cup to the top of the crown. The open space between them represents the end of the anal canal, which is closed variously by from five to ten small irregular pieces surrounding the anal opening, and sometimes by additional larger plates. The anus in some species is drawn out to a tube of great length, extending far beyond the limits of the arms, but more frequently rises but little above the top of the compartments. Arms heavy, arranged in pairs, each pair occupying one of the ten compartments, their backs almost even with the edges of the partitions, their lateral faces abutting against the sides. They have a wide ventral furrow, and are composed from the third or fourth plate up of two rows of short, transverse pieces, which are so closely united by suture, that the arms must have moved *en masse* upon the calyx. Pinnules long and closely folded. The visceral cavity is formed by the plates of the dorsal cup and the two lower rings of plates of the disk; the plates of the two upper rings, which form the neck-like prolongation, being, properly speaking, plates of the anal tube. The ambulacra, on entering the calyx, follow the grooves at the inner floor, and meet near the top of the second ring. Column moderately large, generally round; composed of rather long joints with pentapetalous axial canal. It has no lateral cirri, but branches at the end into hundreds of little rootlets.

*Distribution.* — A leading form of the Upper Silurian, and well represented in this country as well as in Europe. A single species is known from the Devonian: *Eucalyptocrinus rosaceus* from the Eifel of Germany, the *type* of the genus.

*Remarks.* — *Eucalyptocrinus* was originally described by Goldfuss as having no stem; and Phillips, who discovered another species with the stem attached, proposed for this the genus *Hypanthocrinus*. Angelin and Zittel, who accepted Phillips' genus, describe its base as less deeply funnel-shaped, the anal tube as extending beyond the tips of the arms, and the partition walls enclosing the arms as being constructed principally of one piece. Neither one of these characters is constant, and we cannot regard the two forms as distinct generically. That the anal tube rises above the arms is of very little structural value, if we admit that the neck-like prolongation from the disk represents a part of that tube. The earlier writers describe the radials as basals. Roemer discovered the true base in 1843, but he supposed it was quinque-partite, and so did de Koninck and Le Hon. Hall in 1863 found that it consisted of but four plates, and this was confirmed by subsequent authors.

*Eucalyptocrinus* is a most perplexing genus, owing to the peculiar structure of its ventral part, which was apparently not correctly understood by Hall. He described the partition walls as interbrachials; while in fact they are not separate plates, but the outer processes from the plates of the disk and tube, respectively, a sort of compound structure for which we adopt the name "partition walls." The twenty plates forming the lower ring of the disk we regard as large interambulacral plates meeting over the ambulacra; but as to the relations of the plates of the second ring we are somewhat in doubt. We have suggested in Revision, Part III., p. 132, that they probably represented four of the orals, and that the fifth was pushed upward, and constitutes a part of the anal tube. This seems not improbable if we consider that the posterior oral in all Palæozoic Crinoids is pushed more or less out of place by the anus; and it may be expected that this was the case to a high degree in a genus in which the anal tube is large and strictly central.

Miller's *Eucalyptocrinus ellipticus* is too young a specimen to determine its specific relations. A similar specimen from Rochester, N. Y., is figured by us on Plate LXXXIII., Fig. 7.

*Eucalyptocrinus tennesseæ*, *E. Phillipsi*, *E. conicus*, *E. nashvillæ*, *E. extensus*, *E. gibbosus*, *E. lævis*, and *E. Goldfussi*, all of Troost, are mere catalogue names. *E. armosus* McChesney is a *Siphonocrinus*, and *E. cornutus*, *E. excavatus*, both described by Hall, and *E. ramifer* of Roemer, have been referred by us to *Callicrinus*.

### **Eucalyptocrinus cœlatus** (Hall).

*Plate LXXXIII. Figs. 5, 6, 7.*

1843. Geol. Rep. 4th Distr. N. York, p. 113, Fig. 1, and Palæont. N. Y., p. 210, Plate 47, Figs. 4*a*, *b*, *c*, *d*.
1885. W. and Sp. (in part); Revision Palæocr., Part III., p. 133.

Not *Eucalyptocrinus cœlatus* Hall, 1865, Trans. Albany Inst., p. 226 (Abstr., p. 32), and 20th Rep. N. Y. State Cab. Nat. Hist, pp. 321 to 329 (second ed., pp. 363–364), and 28th Rep., p. 142, Plate 16, Figs. 1–10, and Plate 19, Figs. 1–3; also 11th Ann. Geol. Rep. Indiana, p. 274, Plate 15, Fig. 1, Plate 16, Figs. 1–10, Plate 19, Figs. 1–3, all of which we refer to *Eucalyptocrinus Elrodi* S. A. Miller.

Nor *Eucalyptocrinus cœlatus* Roemer; Silur. Fauna West. Tenn., p. 48, Plate 4, Figs. 3*a–e* = *E. ventricosus*.

Syn. (?) *Eucalyptocrinus* (*Hypanthocrinus*) *decorus* Hall, 1843 (not Murchison, 1839); Geol. Rep. 4th Distr. N. York, p. 113, Figs. 2–3, and 1852, Palæont. N. York, Vol. II., p. 207, Plate 47, Figs. 1–3, and Plate 85, Fig. 7.

Syn. *Eucalyptocrinus papulosus* Hall; Palæont. N. York, Vol. II., p. 211, Plate 47, Figs. 5*a*, *b*.

Of medium size. Length of crown compared with the greatest width at the arm bases as 3 to 1, and with the height of the dorsal cup as 3 to 2. The cup subturbinate, uniformly spreading from the middle of the radials to the arm bases, the bottom part somewhat rounded. The plates of the cup densely crowded with small pustules of uniform size, and similar pustules, or small nodes, cover the outer edges of the partition walls to half their height; the upper part being marked by indistinct transverse ridges.

Basal concavity small, completely filled by the upper part of the column. Radials large, wider than long, very slightly inflected, their lower ends thickened by a round, wart-like projection, which is devoid of ornamentation; the sloping upper faces short; the upper face concave. First costals wider than long, the sides all convex, the upper face narrower than the lower. Second costals the size of the first, but pentangular. First distichals smaller than the costals; the second smaller than the first. Plates supporting the arms small and irregularly quadrangular. First interbrachial very large, longer than wide, and tapering downward; the two succeeding ones together almost as large as the first; they rise to a level with the third arm joints, are wider at the bottom than at the top, and unite by a vertical suture. The interdistichals rarely touch the axillary costals; they are twice as long as wide, and one third narrower than both upper interbrachials together. Partition walls almost as thick at the upper end as at the lower, and distinctly rounded on the back. Arms tapering upward to fully one half their greatest width. The four proximal arm plates single and somewhat longer than the others; the two succeeding ones cuneate, and those above arranged in two series, which deeply interlock. The arms are covered with transverse rows of elongate nodes. Anus at the end of a small tube, rising 4 to 5 mm. above the tips of the arms. Ventral part of the calyx not visible in any of the specimens. Column round, the nodal joints very long and rounded at the outer margins, the younger joints short and narrow.

*Horizon and Locality.* — Niagara group; Lockport and Rochester, N. Y.

*Type* specimen in American Museum of Natural History, New York.

*Remarks.* — It is probable that the specimens which Hall referred to *Eucalyptocrinus decorus* Phillips, are identical with this species. They certainly differ essentially from the English species (Plate LXXXII., Fig. 15), which is proportionally shorter and stouter, the plates heavier and more convex, the partition walls thinner, the anal tube stronger, and the column obscurely pentangular instead of round.

The Waldron specimens with ornamented plates, which Hall identified with this species, have been referred by us to *Eucalyptocrinus Elrodi* Miller.

### **Eucalyptocrinus tuberculatus** MILLER AND DYER.

*Plate LXXXIII. Figs. 8, 9, 10.*

1878. MILLER and DYER; Journ. Cincin. Soc. Nat. Hist., Vol. I., p. 36, Plate 2, Figs. 9, 9*a*.
1885. W. and Sp.; Revision Palæocr., Part III., p. 134.
Syn. *Eucalyptocrinus muralis* RINGUEBERG; 1890, Annals N. Y. Acad. Sci., Vol. V., p. 305, Plate 3, Fig. 3.

In its general form resembling the preceding species, but differing somewhat in the proportions of the plates. Dorsal cup obconical, nearly as high as wide, sides slightly convex, the lower end moderately truncated. Plates a little elevated and covered by numerous tubercles of various size, larger ones being interspersed between smaller ones; the suture lines distinctly grooved. Columnar concavity narrow, its depth less than the width; the basals completely covered by the upper end of the column.

Radials considerably longer than wide, rapidly tapering downward, rounded at the bottom; the lower end inflected to meet the basals; the lower face very narrow, equal to one third the width of the upper, which is rather deeply concave; the sloping upper faces short. First costals longer than wide, narrowest at the upper end. Second costals wider than the first, pentangular or hexangular. First distichals from one third to one half smaller than the costals; the second barely one third the size of the first; the arm-bearing palmars very much smaller and triangular. First interbrachials elongate, once and a half as long as wide, and nearly as large as the radials; they are widest next to the intercostal sutures, tapering to both ends; the lower lateral faces convex, and longer than any of the others; the upper faces meeting the interbrachials of the second order. The two latter plates combined are but little smaller than the lower one, their tips rising conspicuously above the arm facets, and very little truncated. Interdistichals much smaller than the corresponding interbrachials, their lower ends touching the costals or resting between the upper sloping faces of the distichals. The remaining parts of the species are not shown in the specimens, but it may be suggested from the condition of the interbrachials and interdistichals that the partition walls were unusually thin.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind., Lockport, N. Y., and Racine, Wis.

*Types* in the Museum of Comparative Zoölogy.

*Remarks.* — Miller and Dyer, in their specific description, after giving the structure of the brachials, and stating that the first interbrachials are "nine or ten-sided," continue as follows: "This description applies to the two ten-sided interradials; the other three have only nine sides, as shown by Plate 2, Fig. 9, and differ in supporting one supraradial instead of two." Even if this were true, which is not the case, it would have no specific significance, but would only indicate an abnormal condition of that specimen. By giving the specimen some additional cleaning, we disclosed two distichals in every ray, all supporting two extremely small palmars, as shown by our figure (Plate LXXXIII., Fig. 9). The peculiarity that some of the interbrachials are nine-sided, is caused by the distichals, which in three of the rays lean over to one side, so that one of them does not touch the interbrachials. In Miller and Dyer's second type, Fig. 9*a* on the same plate, which we also reproduce (Plate LXXXIII., Fig. 8), the respective plates are all ten-sided.

We must regard *Eucalyptocrinus muralis* Ringueberg as specifically identical with *E. tuberculatus*, until better specimens are found. Of Ringueberg's type, which we had for comparison, only the dorsal cup is preserved, and this is so badly crushed as to give no idea of its actual form. It is quite possible that the base is somewhat broader than in Miller and Dyer's types, that the plates generally are a little more convex, and the tubercles upon the plates somewhat less prominent, but the proportions of the plates are substantially the same. Similar variations may be expected in the limits of any species.

### Eucalyptocrinus Elrodi S. A. Miller.

(Revised W. and Sp.).

*Plate LXXXI. Figs. 7a, b, 8, 9, 10, 11, 12, 13.*

1891. S. A. Miller; Ad. Sheets 17th Rep. Geol. Surv. Indiana, p. 40, Plate 7, Figs. 9, 10.
Syn. *Eucalyptocrinus cœlatus* Hall, 1865 (not 1843); Trans. Alb. Inst., p. 226 (Abstr., p. 32); and (?) 20th Rep. N. Y. State Cab. Nat. Hist., p. 321 (revised edition, p. 363), and 28th Rep., p. 142, Plate 16, Figs. 1–10, and Plate 19, Figs. 1–3; also 11th Ann. Geol. Rep. Indiana, p. 274, Plate 16, Figs. 1–10, and Plate 19, Figs. 1–3.
Syn. *Eucalyptocrinus subglobosus* S. A. Miller, 1891, Adv. Sheets 17th Rep. Geol. Surv. Ind., p. 37, Plate 7, Fig. 3.

Usually a little larger than *E. cœlatus*, shorter in proportion, and not attenuate at the poles. General form from subglobose to ovate, the base moderately excavated for the reception of the column. Dorsal cup a little shorter than the height of the partition walls enclosing the arms. The plates of the dorsal cup, as well as the arms, and also the outer edges of the partition walls, marked by numerous round or elongate nodes, often two or three of them confluent and forming straight or vermicular ridges transversely or longitudinally arranged. The nodes upon the arms are in longitudinal rows, there being generally two rows in the upper part of the arms, and four at the lower end.

Basal concavity small and shallow for the genus, the plates completely hidden by the column, forming a short cone at the inner floor. Radials moderately large, the lower ends curving abruptly inward, the remaining parts outward and slightly upward, the lateral faces rapidly tapering, the sloping upper faces short, and the upper face concave. First costals wider than long, the sides convex; the second hexagonal, the upper angle truncated by the interdistichals. First distichals once and a half as large as the second, and the latter more than twice as large as the fixed palmars, which are subtrigonal. First interbrachial very large, the middle part almost as wide as long, the upper end broadly truncated by the interbrachials of the second row. The two latter plates together are longer than wide, having the greatest width at one third their height, whence they gradually slant to the top, which is truncate. The interdistichals are of a similar form, but one third smaller than the two upper interbrachials, and rise, like them, considerably above the level of the arm bases, each supporting also a partition. The outer faces of the partitions are fully twice as wide at the lower end as at the upper, and are slightly grooved. Arms gradually tapering upwards, quite narrow at the extremities, composed of very short pieces; the three or four proximal ones simple, the upper rather deeply interlocking. Ventral disk minus the partitions comparatively high, owing to the plates of the first row which are unusually large; the plates of the second row are shallow funnel-shaped, and those of the third shorter and very heavy. The plates of the fourth row, which form the upper end of the tube, as well as of the compartments, enclose six or eight moderately large plates, and these again a little short cone of eight or ten irregular pieces, which decrease in size inward, and close the anus more or less tightly.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind., and Chicago, Ills.

*Types* in the State Cabinet of Natural History at Albany.

*Remarks.* — The name *Eucalyptocrinus Elrodi* was proposed by Miller for a specimen from Hartsville, Ind., in which the nodes upon the surface are exceedingly regular, and not in part confluent as usually in this species, agreeing in other respects with the specimens from Waldron, which Hall erroneously referred to *E. cœlatus*. The latter species, as represented at Lockport and Rochester, N. Y., its typical localities, is much more elongate than the specimens from Indiana; the dorsal cup is higher and obconical, the radials longer and more nodose at the lower end, the partition walls thinner, their outer edges convex instead of concave, and there is a small tube rising above the walls of the compartments. Whether under these circumstances it is proper to accept for the typical form Miller's name *E. Elrodi*, which he separated from it on account of slight modifications in the ornamentation, may be questioned; but we propose to do so to avoid further synonomy. We therefore include in this species not only Miller's special form, but also the specimens from Waldron and Hartsville, figured by Hall under *E. cœlatus*, and also Miller's *E. subglobosus*, which latter we regard an immature form of this species.

### **Eucalyptocrinus ornatus** Hall.

*Plate LXXXII. Fig. 10.*

1867. Hall; 20th Rep. N. Y. State Cab. Nat. Hist., p. 329, Plate 11, Figs. 4 and 5.
1885. W. and Sp.; Revision Palæocr., Part III., p. 134.

The dorsal cup, the only part known of this species, was described from internal casts and gutta percha impressions, taken in the natural mould of the exterior. It is depressed, as wide as high, the radials directed horizontally, except their extreme lower ends, which take part in the basal concavity. Costals, first distichals and first interbrachials curving rapidly upwards, so that the sides near the top of the cup are parallel with corresponding parts of the opposite side. Surface of plates, as shown from the gutta percha impressions, beautifully ornamented with elongate nodes or ridges passing out from the centres of the plates to their sides, but not continued to adjoining plates.

Basal concavity narrow, and moderately deep. The radials rapidly tapering to their lower ends and rather small, not larger than the second costals, which are considerably larger than the first. First costals quadrangular, once and a half as wide as long; the second hexagonal, being truncated at the upper end. First distichals about a third smaller than the upper costals; the second quite small and the palmars still smaller. First interbrachial larger than the radials, almost as wide as high, those of the second row together smaller than the first; the interdistichal sub-rhomboidal, the upper and lower angles truncated.

*Horizon and Locality.* — Niagara group; Racine, Wisc., and Chicago, Ills.

*Remarks.* — The basal concavity in the casts is deeper than it appears in the gutta percha impressions, and there are shallow grooves passing out from it in a radial direction, which are not seen upon the impressions, and give to the cavity in that state of preservation a decidedly pentapetalous aspect. In specimens in which the plates are but partly dissolved, the surfaces generally show concentrating lines around the margins of the plates, which probably represent mere lines of growth.

### **Eucalyptocrinus ventricosus** W. and Sp. (nov. spec.).

*Plate LXXXIII. Figs. 11 and 12.*

Syn. *Eucalyptocrinus cœlatus*, Roemer, 1860 (not Hall 1843); Silur. Fauna West. Tenn., p. 48, Plate 4, Figs. 3 *a–e*.

A small species, in its general form subovate, slightly depressed at the poles, its greatest width a little above the arm bases. Dorsal cup low saucer-shaped, the sides evenly rounded, its height less than half the length of the arm compartments; the plates flat or nearly so, marked in well preserved specimens by irregular, delicate lines running to the sides, but not communicating with those of adjacent plates.

Basal concavity narrow and very deep, obscurely pentangular at the outer margin; the basals very small, occupying only the bottom part. Radials very long, only half their length exposed to view; the attenuate longer half incurving and forming the sides of the concavity; the exposed part wider than high. First costals quadrangular, their width once and a half their length; the second a little larger and hexangular, their upper angle broadly truncated by the interdistichals. Distichals nearly of equal size, and almost as large as the axillary costal; the upper angle of the second so extremely obtuse as to almost form a straight line; the fixed palmars moderately large and quadrangular. First interbrachial large, generally as wide as long; the upper part broadly truncated by the two plates of the upper row, which together are as large as the first, and rise to the second arm plate. Interdistichal rather narrow and long. Partition walls narrow, not more than half the width of the arms, except their upper ends which widen conspicuously toward the summit. Summit somewhat flattened; the central space closed by a short pyramid of small plates. The arms rounded on the back, projecting slightly over the sides of the partitions; the three proximal plates single, and higher than the succeeding ones which deeply interlock.

*Horizon and Locality.* — Niagara group; Decatur and Wayne Cos., Tenn.

*Types* in the Museum of Comparative Zoölogy, and in the collection of Wachsmuth and Springer.

*Remarks.* — This species differs from *E. cœlatus*, to which Roemer referred it provisionally, by the much more depressed form of the dorsal cup, the proportionally greater length of the arms, the form and size of the various plates, and the mode of ornamentation.

### **Eucalyptocrinus crassus** Hall.

*Plate LXXXI. Figs. 1, 2, 3, 4, 5, 6, 14, 15.*

1863. Hall; Trans. Albany Inst., Vol. IV., p. 197; also 20th Rep. N. Y. State Cab. Nat. Hist., p. 323, Plate 11, Figs. 2, 3 (second ed., p. 365); also, 28th Rep. (second ed.), p. 141, Plate 17, Figs. 1–11, Plate 18, Figs. 1–9, and Plate 19, Figs. 2–5.
1875. (?) Hall and Whitfield; Geol. Surv. Ohio, Palæont., Vol. II., p. 129, Plate 6, Fig. 11.
1881. Collett; 11th Ann. Rep. of Geol. and Nat. Hist. of Indiana, p. 272, Plate 17, Figs. 1–11, Plate 18, Figs. 1–9, and Plate 19, Figs. 2–5.
Syn. *Eucalyptocrinus constrictus*, Hall; ibid., p. 273, Plate 15, Fig. 1.
Syn. *Eucalyptocrinus chicagoensis*, Winch. and Marcy; 1865, Mem. Boston Soc. Nat. Hist., p. 90.

A large species; the crown sometimes reaching a length of 10 cm. by 6 cm. in width; its length, as a rule, twice the width; the length of the dorsal cup to the top of the interbrachials and interdistichals almost equal to the height of the compartments for the reception of the arms. Dorsal cup subturbinate, massive, broadly truncate at the lower end, and the bottom part deeply excavated, the sides straight or a little concave; surface of the plates flat and without ornamentation; the suture lines obscure.

Basals small, at the bottom of a deep, funnel-shaped concavity, and forming with the inflected lower part of the radials, at the inner floor, a rather large cone with a pentapetalous axial canal of moderate size. Radials very large, much longer than wide, forming a broad, slightly spreading cup, which extends out laterally far beyond the sides of the column. First costals quadrangular; their length and breadth equal; the greatest width at the base; the lower and lateral faces convex. Second costals smaller than the first, generally pentangular, occasionally the upper angle slightly truncated by the interdistichal. First distichals almost as large as the axillary costals; the second but one third the size of the first. First palmars very short and trigonal. First interbrachial almost as large as the radials; length to width as 5 to 3; its greatest width at the intercostal suture line, whence it rapidly tapers to both ends; all sides concave. The two plates of the second row either separated from the first, or lightly touching its upper angle, and both together about two thirds the size of the first; they rise above the arm bases in form of a square projection. The interdistichal is of a similar form as the two upper interbrachials, but one third smaller. Ventral disk, deprived of its appendages, pyramidal, the neck-like upper part proportionally long, widening at the top, the compartments surrounding it deep. These are constructed of the keel-like partitions ascending from the back of the plates of the first row, and the wing-like extensions of the upper row, which meet each other at the middle of the third row, resting with their inner edges against the protruding surfaces of the plates constituting the second and third rows. The form of the plates of the first ring, as viewed from the inner cavity, is similar to that of the first interbrachials; they are as large, and also attenuate at both ends. The plates of the second ring, which are quite massive and elongate, form a reversed funnel with its long tube pointing upwards; those of the third ring are short and narrow, and those of the fourth rather long and wider above than below. The canal within the neck widens toward the extremity, and the top is closed by a short pyramid of small, irregular pieces surrounding the anus, which is generally closed in the specimens. The edges of the partition walls taper considerably upward, being quite thin above, rather thick below. Arms flattened at the back, stout, a little tapering at the upper end. They are composed of extremely short, tranverse pieces, which very slightly interlock; the four proximal joints single and resting between the protruding upper parts of the interbrachials and interdistichals. In very mature specimens, in which these projections are comparatively longer, they sometimes enclose 5 to 6 joints. Column tapering downward, the joints much the longest at the upper end; the nodal joints long, and wider than the intervening younger ones, their outer margins slightly convex; the joints near the root very short and of uniform size. The root is composed of hundreds of small branchlets, most of which are run out horizontally.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind., Green Co., O., and Chicago, Ills.

*Types* in the American Museum of Natural History at New York.

*Remarks.* — This species is extremely variable in form and proportions, but, as a rule, the cup in the older specimens is more elongate, and not unfrequently constricted near the middle, thereby producing a slight concavity at the sides. The base in some specimens is so broad as to give to the cup a subcylindrical outline. In all specimens, however, the base extends far out beyond the sides of the stem, and this, together with the unusual length of the first costals, and the extreme shortness of the arm joints, distinguishes it readily from all other American species of this genus.

### **Eucalyptocrinus ovalis** (Troost) Hall.

*Plate LXXXII. Figs. 1, 2, 3, 4, 5, 6.*

1849. *Eucalyptocrinus ovalis* — Troost; Catalogue of Crinoidea.
1874. *Eucalyptocrinus ovatus* (in error for *E. ovalis*) — Hall; first edit. 28th Rep. N. Y. State Mus. Nat. Hist., Plate 17, Figs. 12 and 13 (the error rectified in the second edit. of the same report in the explanation of the plates).
1885. *Eucalyptocrinus ovalis* — W. and Sp.; Revision Palæocr., Part III., p. 134.

A small species. General form ovoid, curving regularly from base to summit. Height to width as four to three in mature specimens, and six to five in very small ones. Greatest width a little above the top of the dorsal cup. Height of the cup, compared with the height of the partition walls, as two to three. Surface of plates smooth and without ornamentation; the suture lines indistinct.

Basal concavity a little wider than the column, and rather deep, the basal plates occupying almost its whole width. Radials curving abruptly inward at the lower end, forming a sharp edge at the bottom of the dorsal cup; the exposed upper part wider than long, and nearly as large as both costals together. First costals once and a half as wide as long; the second a little wider and pentangular. First distichals almost as large as the costals, the second one third smaller, and the arm-bearing palmars about half the size of the second distichals and pentangular. First interbrachial large, subcircular in outline though actually decagonal; it meets the two succeeding plates, which are as long as the first, and near the lower end almost as wide; the upper parts tapering rapidly to a rather sharp point, which rises to the height of the fourth arm pieces. Interdistichal narrower and shorter than the two upper interbrachials; the lower end angular and barely touching the upper angle of the adjoining costal; the projecting upper end narrow and truncate. Compartments for the reception of the arms deep; the partition walls thin throughout, their width at the lower end half that of the arms, the outer faces flat. The summit closed by a small rosette of about eight pieces without additional plates. Arms very gradually tapering, the outer face slightly convex; they are composed of moderately short pieces, which interlock from the fourth plate. With the exception of the partitions nothing is known of the construction of the disk. Column round, the nodal joints high and cylindrical, the younger joints a little narrower; axial canal pentalobate.

*Horizon and Locality.* — Niagara group; Waldron and Hartsville, Ind.

*Types* in the American Museum of Natural History at New York.

*Remarks.* — This species has such close affinities with *E. crassus* that it might be taken for its younger stage; but on close inspection it will be observed that the specimens have all the characteristics of an adult form. The arms not only are biserial, but their plates are almost transversely arranged. Moreover, the arms are placed deeply in between the projecting upper ends of the interbrachials and interdistichals; only in young specimens the tips are almost on a level with the distal faces of the arm-bearing palmars. It differs from *E. crassus* in its much smaller size, being only from 12 to 22 mm. in length by from 10 to 15 mm. in width, in the more evenly ovate form of the crown, in not being truncated at the lower end, and in having much shorter costals, and proportionally larger and pentangular arm-bearing palmars.

### **Eucalyptocrinus inconspectus** Ringueberg.

*Plate LXXXIII. Figs. 1 and 2.*

1884. Ringueberg; Proceed. Acad. Nat. Sci. Phila., p. 148, Plate 3, Fig. 5.

Of rather large size. Dorsal cup deep, occupying almost one half of the length of the crown; semi-ovoid, the sides decidedly convex, rising gradually to the middle of the second costals, thence almost vertically to the top, so that the plates at the upper end are parallel to those of the opposite side. Plates flat — the general curvature excepted — and without ornamentation or other markings,* the suture lines indistinct.

Basal concavity narrow and filled completely by the upper part of the column. Radials about as long as their width near the top, rapidly tapering downward, the extreme lower end gently curving inward and taking part in the columnar concavity; the sloping upper faces very short. First costals as wide as long, a little narrower at the upper end, the sides slightly convex. Second costals as long as the first, widest at two thirds their height, sometimes the upper angle slightly touched by the interdistichals. First distichals a third smaller than the upper costal, the second very small, and the succeeding palmars still smaller and irregularly pentangular. First interbrachial extremely large, decagonal, about a third longer than wide, attenuate at both ends; the two of the second row shorter, and together narrower than the first, their upper and lower ends forming re-entering angles. The interdistichal approaching the two upper interbrachials in form, but considerably smaller; its upper end squarely truncated, and rising to the third arm plate. Partition walls narrower than the arms, and of uniform width throughout; their outer edges flat at the proximal, and convex at the distal end. Arms gradually tapering, rounded exteriorly; the three lower joints single, and a little longer than the upper, which are extremely short. Structure of disk and summit unknown.

*Horizon and Locality.* — In the white limestone at the upper part of the Niagara group; Rochester, N. Y.

*Remarks.* — Nearest to *E. crassus,* but the sides of the dorsal cup distinctly rounded, the base not truncated, and the basal concavity very much smaller.

* Ringueberg described the surface as "finely rugose; rugæ giving evidence of irregular radiations from the larger plates." We have carefully examined his type, but cannot discover any ornamentation; the roughness upon the surface is evidently caused by weathering.

**Eucalyptocrinus Lindahli** W. & Sp. (nov. spec.).

*Plate LXXXII. Fig. 9.*

1892. American Geologist, Vol. X. (September), p. 139.
Syn. *Eucalyptocrinus Wortheni* S. A. Miller; 1894, Geol. Rep. Ill., Bull. 3, p. 53, Plate 4, Fig. 2.

Above medium size. Most remarkable for its heavy, rounded arms, which to their full length are elevated prominently above the outer faces of the partition walls, so that the latter form the bottom of a deep groove. Dorsal cup semi-globose, its lower concavity not larger than the width of the stem, and enclosing only the basals, which are hidden from view by a narrow, round stem. Plates not distinctly ornamented, merely showing a roughened surface. Suture lines slightly grooved.

Radials rather large, as long as wide, rapidly sloping to the lower end; their lateral faces three times as long as the slanting upper ones; the superior face concave. First costals quadrangular, smaller than the radials, a little wider than long. Second costals hexangular, wider and longer than the first; their sloping upper faces longer than any of the others; the upper angle slightly truncated by the interdistichal. First distichals smaller than the axillary costals, the second less than half the size of the first, and subquadrangular. Palmars three in the calyx, transversely arranged, rounded on the back. First interbrachial ten-sided, as large as the radials, longer than wide, widest at the middle; the two of the second row nearly three times as long as wide, rising to the height of the third palmars. The interdistichal a little shorter and narrower than the two upper interbrachials combined. The walls forming the compartments taper gradually to near the upper end, then widening rapidly, and curving abruptly inward so as to form a flat surface at the summit on a level with the tips of the arms. Arms rather short, very heavy, almost cylindrical. They rise above the sides of the partitions much more conspicuously than is known to be the case in any other species, their tips being lifted out from between them almost completely.

*Horizon and Locality.* — Niagara group; Wayne Co., Tenn.

*Type* in the Illinois State collection.

The species is named in honor of Dr. Josua Lindahl, the eminent Zoölogist and Director of the State Museum at Springfield.

**Eucalyptocrinus magnus** Worthen.

*Plate LXXXII. Figs. 7, 8.*

1875. Worthen; Geol. Rep. Illinois, Vol. VI., p. 501, Plate 25, Fig. 3.
1885. W. and Sp.; Revision Palæocr., Part III., p. 133.
Syn. *Eucalyptocrinus Gorbyi* S. A. Miller; Adv. Sheets 17th Rep. Geol. Surv. Missouri, p. 39, Plate 7, Figs. 5, 6.

A large species. Dorsal cup depressed turbinate, height and width about as seven to ten; the lower end obtusely conical, rapidly spreading from the top of the radials to the top of the first distichals, then abruptly turning upwards until at the upper end the sides are parallel with those of the opposite side. The upper interbrachials somewhat depressed, so as to give to the cup, as seen from above, an obscurely pentalobate outline. Plates almost flat; the surface smooth or finely granulose; suture lines slightly grooved.

Basal concavity narrow, completely filled by the column. Radials, as exposed to view, wider than long, rapidly spreading upward, their upper faces twice as wide as the lower. First costals somewhat smaller and quadrangular; the sides slightly convex. Second costals heptangular, wider and longer than the first; the sloping upper faces convex and unusually steep; the upper angle broadly truncated by the interdistichal. First distichals as large as the axillary costal; the second less than half the size of the first; the arm-bearing palmars trigonal and quite small. First interbrachials the largest plates of the cup; decagonal, but sub-rhomboidal in outline; the sides more or less concave. The two plates of the second row together wider than the first, with re-entering angles at the upper and lower ends. Interdistichals large, elongate, rising to the height of the fifth arm plate, the sides facing the costals concave, the upper and lower faces broadly truncated. Of the arms only a few of the lower plates were preserved, which are extremely short. The partition walls are broken away in the specimens, but were, to judge from the places for their attachment, unusually heavy.

*Horizon and Locality.* — Niagara group; White's creek, near Nashville, Tenn., and Decatur and Wayne Cos., Tenn.

*Type* in the collection of Prof. S. S. Gorby.

*Remarks.* — This species is most remarkable for its large size, and is readily distinguished from all other known species by its peculiar form.

**Eucalyptocrinus depressus** S. A. Miller.

*Plate LXXXIII. Figs. 3, 4a, 4b.*

1880. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. III., p. 232, Plate 7, Figs. 1, 1a, b.
1885. W. and Sp.; Revision Palæocr., Part III., p. 133.

Of moderate size. Crown subcylindrical, twice as high as wide, a little tapering to the upper end, distinctly flattened and concave at the poles. Dorsal cup almost twice as wide as high, the upper part of the radials and the extreme ends of the first interbrachials forming the truncated bottom, the upper part of the latter and the first costals gently curving upward, the plates above parallel to those of the opposite side. Plates a little convex, their surface apparently rugose. Lower concavity deeply and broadly funnel-shaped, the basals constituting but little more than the bottom part.

Radials slightly longer than wide; their upper half more or less horizontal in position, and not visible from a side view; the lower half forming the slanting sides of the concavity; their sloping upper faces rather long. First costals twice as wide as long, a little shorter than the second at the median line; the upper end of the latter slightly truncated by the interdistichal. First distichals about a third smaller than the upper costals; the second half the size of the first, their upper angles quite obtuse; the first palmars very small and pentangular. First interbrachial subrotundate, as long as wide, those of the second row as long, but together narrower than the first, their upper ends rising to the base of the second arm plates. The interdistichal has almost the form of the two upper interbrachials, but is somewhat smaller. Partition walls nearly twice as long as the dorsal cup, moderately thin, the outer edges rounded to near the top, then slightly widening and curving abruptly inward and somewhat downward, so as to form a shallow depression around the summit. Their upper ends enclose five rather large plates with a pentangular open space, the overlying plates being not preserved in the specimen. The height of the calyx, as observed in the casts, is about equal to the greatest width across the first distichals, and that of the dorsal cup equal to that of the tegmen but narrower; the tubular prolongation above almost as long as the rest of the calyx, widening at both ends. Of the arms only the proximal plates are preserved, which are comparatively long.

*Horizon and Locality.*—Niagara group; Cicero and Bridgeport, near Chicago, Ills.

*Types* in the collection of W. C. Egan, Esq., of Chicago.

*Remarks.* — This species differs from all preceding ones in the depressed form of the dorsal cup, the width and depth of the basal concavity, and the position of the radials which are almost at right angles to the plates of the upper end. It was originally described from natural casts, but Mr. Egan has since obtained from the same locality a specimen with the plates intact, from which our description is made.

*Doubtful species described from natural casts.**

**Eucalyptocrinus splendidus** (Troost) Hall and Whitfield.

1848. Troost; List Crin. Tenn., Proceed. Amer. Assoc. Adv. Sci., p. 60 (without description).
1875. Hall and Whitfield: Geol. Surv. of Ohio, Palæont., Vol. II., p. 128, Plate 6, Fig. 12.

Closely allied to the preceding species, and perhaps identical with it. As in that species, the general form is subcylindrical, flattened at both ends, the arms are twice as long as the dorsal cup, and the radials are not seen in a side view, or only their extreme upper ends; the disk, however, to judge from the cast, is proportionally shorter, and the first costals are higher. The basal concavity cannot be seen in the specimen, but must have included the greater part, if not the whole, of the radials. First costals quadrangular, nearly as long as wide; the apex of the second slightly truncated by the interdistichal; the distichals considerably smaller than the costals; the first interbrachial large, a little longer than wide. The proportions of the other plates indeterminable. Disk hemispherical, the tubular canal in the cast as long as the rest of the calyx, and funnel-shaped at the upper end.

*Horizon and Locality.* — Niagara group; Springfield, O.

*Type* in the collection of Professor Orton.

**Eucalyptocrinus rotundus** S. A. Miller.

1882. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 82, Plate 3, Figs. 4 and 4 *a*, *b*, *c*.

Of small size. Crown globose. The inner cavity of the calyx, as seen in the cast, much wider than high, the canal within the neck wide and of nearly uniform width. Dorsal cup low-saucer shaped; the basal concavity small, and apparently filled completely by the upper joints of the column. Radials wider than long, the upper face concave. First costals twice as wide

* We are willing to admit that most of these forms differ specifically from one another, but we are unable to see how the casts can be satisfactorily compared with species described from the test, especially in a genus like *Eucalyptocrinus* in which the differentiations are but very slight.

as long. Second costals about the size of the first, a little higher at the median line, their upper end slightly truncated by the interdistichal. First distichals almost as large as the costals. The form of the other plates indeterminable.

*Horizon and Locality.* — Niagara group; near Chicago, Ills.

*Types* in the collection of W. C. Egan, Esq., of Chicago.

*Remarks.* — This may be a small specimen of *E. Elrodi*, with which it agrees in the general form, and in the proportionate size of the plates.

### **Eucalyptocrinus turbinatus** S. A. Miller.

*Plate LXXXII., Fig. 13.*

1882. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., p. 82, Plate 3, Figs. 5 and 5 *a*.

A rather large species. In the cast, the calyx is nearly as high as wide, the dorsal cup obconical, slightly constricted above the radials, the extreme upper end abruptly curving upwards; the suture lines are defined by angularities, and the inner spaces of the plates are slightly concave. The disk appears depressed hemispherical, with ten well-marked longitudinal ridges representing the ambulacral grooves.

Basal concavity moderately deep and obscurely pentangular. Radials, as exposed in a side view, comparatively small, wider than long. First costals quadrangular, nearly as long as wide. Second costals pentangular, a little larger than the first, the sloping upper sides steep, the upper angle truncated by the interdistichal. First distichals as large as the second costal; the second much smaller; the palmars minute. First interbrachial a third longer than wide, barely touching the radials. The two plates above forming a rhomb with the two acute angles truncated. Interdistichal comparatively short. Length of the partition walls, and the neck-like prolongation of the calyx not known.

*Horizon and Locality.* — Same as last.

*Type* in the collection of Mr. W. C. Egan.

*Remarks.* — This is probably a good species. Fragmentary specimens with the plates intact, apparently representing this form, occur in the Niagara group of Decatur Co., Tenn. The basal concavity is narrow, and the radials have a truncation at the bottom, of which the edges project rather broadly over the sides of the column. The truncated upper faces of the interbrachials and interdistichals supporting the partition walls are extremely wide, the facets for the reception of the arms are surrounded by a raised angular edge, and the plates are covered with obscure radiating ridges or rows of small tubercles.

### **Eucalyptocrinus Egani** S. A. Miller.

*Plate LXXXII. Figs. 11 and 12.*

1880. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. III., p. 140, Plate 4, Figs. 1 *a–c*.

A very elongate species. Height and width of calyx as 8 to 5; height of dorsal cup, compared with the length of the arms, as 2 to 5; the length of the neck-like prolongation to the tips of the partitions as 8 to 9 — all measurements made from the casts. Dorsal cup a little higher than wide, obconical, the bottom distinctly truncated and not excavated in the cast, the sides very slightly convex and projecting conspicuously over the sides of the disk. Radials nearly as long as wide. The first costals longer than wide, and narrower above than below; the second of the same length, and truncated by the interdistichals. Distichals a third smaller than the costals. First interbrachials almost twice as long as wide, widest at midway. Form of the remaining plates indeterminable. Ventral disk but slightly tapering, its upper margin curving abruptly to the base of the neck, which expands rapidly upwards. It rises apparently far beyond the arms, and tapers in size as rapidly as it increases below.

*Horizon and Locality.* — Same as last, and the type specimens in the same collection.

### **Eucalyptocrinus proboscidalis** S. A. Miller.

*Plate LXXXII. Fig. 14.*

1882. S. A. Miller; Journ. Cincin. Soc. Nat. Hist., Vol. V., Plate 9, Fig. 2.

Closely allied to the preceding species, but the calyx, to judge from the cast, still more elongate, being to the b se of the neck over twice as long as wide; the sides of the dorsal cup more convex; the tegmen higher proportionally, less depressed at the top, and more evenly rounded. The neck is more constricted in the middle, and more expanding at the summit, the tube succeeding it thicker at the base, and apparently longer, reaching in the type a length of 43 mm. by 12 mm. in width at the base, and 2 mm. at the upper end, tapering gradually. The plates of the dorsal cup, so far as observed, are long, especially the first interbrachials, which are more than twice as long as wide, occupying fully one half the length of the dorsal cup. The tube in its free state was covered by large hexagonal plates, very regularly arranged.

*Horizon and Locality.* — Niagara group; Pontiac, O.

*Remarks.* — Miller described this species from a plaster cast in the possession of Mr. A. McCord of Oxford, Butler Co., O.

### Eucalyptocrinus obconicus Hall.

*Plate LXXXIII., Fig. 13.*

1867. Hall; 20th Rep. N. Y. State Museum Nat. Hist., p. 323, Plate 11, Fig. 1.
1885. W. and Sp.; Revision Palæocr., Part III., p. 133.

Differing from all other American species of this genus in the arrangement of the basals, which form an obconical cup instead of being placed within a concavity. Dorsal cup very long, sometimes almost twice as high as wide, sharply pointed at the lower end, the sides straight to near the top, where they slightly contract. Radials once and a half as long as wide, but very little tapering, the sloping upper faces quite small. First costals quadrangular, as long as wide, the upper face narrower than the lower; the second costals of about the same size as the first, but pentangular. First distichals comparatively large, those of the same ray in contact laterally; the second very small. First interbrachials nearly twice as long as wide, widest at midway; the two of the second row shorter. Interdistichals unusually small, resting upon the sloping upper faces of the first distichals. All other parts unknown.

*Horizon and Locality.* — Niagara group; Racine, Wisc., and Chicago, Ills.

## CALLICRINUS d'Orbigny.

1850. D'Orbigny (*Calliocrinus*); Prodrôme, Vol. I., p. 45.
1878. Angelin; Iconogr. Crin. Suec., p. 14.
1879. Zittel; Handb. d. Palæont., Vol. I., p. 378.
1881. W. and Sp.; Revision Palæocr., Part III., p. 135 (Proceed. Acad. Nat. Sci. Phila., p. 357).
1890. Ringueberg; Annals N. Y. Acad. Sci., Vol. V., p. 302.
Syn. *Eugeniacrinites* Hisinger (not J. S. Miller), 1857, Lethæa Suec., p. 86.
Syn. *Eucalyptocrinus* (in part) Hall; N. Y. State Mus. Nat. Hist., p. 322 (20th Rep.).

In its general aspect, in the form of the calyx and arrangement of the plates, closely resembling *Eucalyptocrinus.* The calyx also has the form of a wine bottle with long slender neck, and a deep concavity at the bottom; but the partition walls, instead of forming closed compartments to the full length of the arms, rise only to a certain height, and are not closed from above. The plates, as a rule, are highly ornamented, strongly nodose, or extended into long spines. The dorsal cup is constructed of the same number of plates, and arranged in exactly the same manner as in *Eucalyptocrinus;* generally, however, the basal concavity is wider, and only partly filled by the column. In the construction of the ventral disk also, the two genera have close affinities; the plates in both forms consist of four rings, and in both of them the first ring is composed of twenty plates, the second and third of four; but the fourth ring contains but four plates instead of ten. and these have no wing-like extensions at their outer faces; the upper parts of their arms are free, and rest directly against the walls of the anal tube. The partition walls, of which there are twenty in this genus. are restricted to the plates of the first ring, and rise but little above their general height, never touching the plates of the second ring. Five of the partitions are supported by the interbrachials, five by the interdistichals; the remaining ten are interposed between the ten others, and rest upon the edges of two palmars. These latter partitions are formed by wing-like extensions from the ten smaller plates of the first ring; they rise to the same height as the others, and separate the two arms which in *Eucalyptocrinus* occupy the same compartment. The plates of the second and third rings either are flat, the general curvature excepted, or they show some inclination to forming faces of attachment for partition walls. The four plates of the upper ring constitute the upper end of the anal tube, which generally has a quadrangular opening. Arms robust throughout, closely folded, and composed, from the second or third plate up, of two rows of transverse pieces. The partitions by which they are separated rarely extend up higher than to one third the length of the arms. Column round; the axial canal of medium size and pentangular.

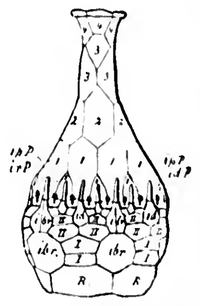


FIG. 17. *Callicrinus.* Side view of calyx, showing the rudimentary partitions.

*R* = radials; *I* = costals; *II* = distichals; *ibr* = interbrachials; *id* = interdistichals; *irP* = interradial partitions; *idP* = interdistichal partitions; *ipP* = interpalmar partitions; *1* = the first or lower ring of plates in the tegmen, composed of ten large and ten small subtrigonal pieces; *2* = the plates of the second ring, *3* = those of the third ring, *4* = the plates of the fourth ring.

*Distribution.* — The greatest number of species occurs in the Upper Silurian of Gotland, and there are one or two at Dudley, England. The genus is represented in America by four species in the Niagara group.

*Callicrinus costatus* (Hisinger) is the type of the genus.

*Remarks.* — *Callicrinus* is probably the forerunner of *Eucalyptocrinus;* it is built on the same plan, but its family characters were not, as yet, so highly differentiated as in that genus.

### **Callicrinus Beachleri** W. and Sp.

*Plate LXXXIII. Figs. 14a, b.*

1892. W. and Sp.; Amer. Geologist, Vol. X. Sept., p. 140.

The calyx has the usual form of the genus. Its height to the base of the tube one fourth greater than the width at the top of the dorsal cup; the height of the cup 11 mm., that of the ventral disk 16 mm., and the length of the partition walls 8 mm. Dorsal cup broadly truncated at the base; the sides almost straight, gradually expanding upwards. The radials and costals at the surface sharply keel-shaped, especially the former, and the angularity continued upon the distichals, but without attaining the prominence that it has at the lower plates; the first interbrachials slightly convex, with a small tubercle in the centre.

Basals small and nearly of the same size, forming a concavity which is rather small and shallow for the genus. Radials near the upper end fully as wide as long, and twice as wide as at the lower part, which curves gently inward to meet the basals. First costals twice as wide as long; the second, which are longer and wider, rarely truncated by the interdistichal. First distichals twice as large as the second, and but little smaller than the upper costals. The palmars small and pentangular. First interbrachials longer than wide, a little smaller than the radials; the two above together nearly twice as wide as the first, their upper ends rising to the height of the second or third arm plates. Interdistichals but little smaller than the upper interbrachials, and projecting upward in a similar manner. Ventral disk conical, its sides convex. The ten plates which rest upon the interbrachials and interdistichals, respectively, and form the compartments for the reception of a pair of arms, are twice as high as the ten intervening ones, which rest against the sloping upper faces of the palmars. There are in all twenty partitions around the disk, and each arm occupies a separate compartment. The partition walls are moderately thick, and slightly grooved along their outer faces. The ten larger ones rise to a level with the upper end of the first ring of plates in the disk, of which they form wing-like extensions; they are sabre-shaped and pointed at the ends. The second ring of the disk consists of four plates, which are much narrower at the top than at the bottom, and two of them are narrower than the others. Construction of the anal tube, its length, and the structure of the arms unknown.

*Horizon and Locality.* — Niagara group; St. Paul, Ind.

*Type* in the collection of Wachsmuth and Springer.

*Remarks.* — The unique specimen from which the above description is made, was discovered by Mr. Charles S. Beachler, a very enthusiastic collector, in whose honor the species is named. He has since found a second specimen at the same locality.

### Callicrinus acanthinus Ringueberg.

*Plate LXXXIII. Fig. 18.*

1890. Ringueberg; Annals N. York Acad. Sci., Vol. V., p. 302, Plate 3, Figs. 1 and 1*a*.

The specimens from which this species was described are quite fragmentary, only showing portions of the dorsal cup, and nothing of its superstructure, but enough is seen to indicate that the species is unlike any other heretofore described. The dorsal cup evidently was very short, shorter even than represented in Ringueberg's restored figure in the Annals, Plate 3, Fig. 1, the lower ends broadly truncated, and almost as wide at the bottom as at the top. The cup rests upon the median part of the large radials; the lower end of the plates curves inward to meet the four basals, and the upper end abruptly upwards.

The basals, together with the lower part of the radials, form a deep pentapetalous concavity, which at the inner side of the calyx is represented by a short cone, rounded at the upper end. First costals twice as wide as long, the suture lines convex; the second a little longer, their sloping upper faces at right angles. The first distichals in contact laterally, somewhat smaller than the upper costals, wider than long, the upper face concave; the second much smaller, and the arm-bearing palmars smaller still. First interbrachials almost as large as the radials, a little longer than wide, subrotundate in outline; the two plates above elongate, and together much smaller than the first. The interdistichal very small, resting within a notch formed by the first distichals. The faces supporting the partition walls projecting considerably over those supporting the arms. The axillary costals and first interbrachials are extended into long, rather sharp spines, proceeding from the middle of the plates and directed obliquely upward. In addiion to the spines, the plates have strong ridges or angular protuberances passing out to the sides, where they meet with similar ridges from the plates below. The radials have six such ridges, one proceeding to the first costals, one to the basals, two communicate with those of the interbrachials, and the two remaining ones, which form a well defined pentagon at the lower margin of the cup, pass out to the adjacent radials. The smaller plates in the upper part of the dorsal cup are convex, and slightly angular in the middle.

*Horizon and Locality.* — Lower limestone of the Niagara group, Lockport, N. Y.

*Type* in the collection of Dr. E. N. S. Ringueberg.

*Remarks.* — Differing from all other American species in the depressed form of the dorsal cup, the surface markings of the plates, and in the number, form, and direction of their spines.

### Callicrinus cornutus Hall.

*Plate LXXXIII. Figs. 15, 16, 17.*

1867. *Eucalyptocrinus cornutus* — Hall; 20th Rep. N. Y. State Cab. Nat. Hist., p. 322, Plate 11, Figs. 8, 9, 10.

1882. *Eucalyptocrinus cornutus* — R. P. Whitfield; Geol. Rep. Wisc., Vol. IV., p. 285, Plate 16, Figs. 5–8.

1885. (?) *Eucalyptocrinus cornutus* — W. and S.; Revision Palæocr., Part III., p. 133.
Syn. *Eucalyptocrinus cornutus*, var. *excavatus* Hall; 20th Rep. N. Y. State Cab. Nat. Hist., p. 322, Plate 11, Figs. 6, 7.

Calyx, as seen from internal casts, more than twice as wide as high, dorsal cup broadly truncated, and enormously excavated at the bottom, the sides but very slightly expanding upwards, being almost vertical. The excavation at the bottom extends to nearly the full width of the cup, and to two thirds its height; the circumference is sharply pentangular with straight or slightly re-entering sides, the inner face grooved toward the angles, which are directed radially. The arrangement of the plates is rarely seen upon the internal casts, and not much better in the gutta percha impressions from the exterior. In the latter, however, it appears that the middle of each radial bears a long spine, which passes outward and slightly upward, and occupies the lower margin of the cup. From each side of these spines, strong ridges proceed to the upper lateral margins of the plates, which meet with similar ridges from the interbrachials. A somewhat larger ridge runs to the costals, where it divides and sends a branch to the distichals. From the lower side of the spine there is but one ridge, which leads to the basals. The ridges upon the first interbrachials culminate in a sharp node in the centre.

Basals comparatively small, occupying but half the depth of the concavity. Radials very large, the lower half curving abruptly inward, and forming a sharp edge upon which the cup rests. Costals very small, the two together less than half the size of the radials; the first from two to three times as wide as long; the second a very little higher and truncated at the top. Distichals, palmars, and interdistichals very small; the first interbrachial unusually large, and as wide as long. Ventral disk stout, and to the base of the tube twice as high as the dorsal cup; the sides rising vertically to the top of the trigonal plate of the first ring, whence they slope slightly to the summit of the ten larger ones, and more rapidly to the tube, which near its base is moderately thick. The ten larger plates of the first ring are longer than the whole dorsal cup, the intervening trigonal ones but half as long. The former, as seen from gutta percha impressions, have long spiniform appendages, which probably resembled those of *Callicrinus murchisonianus* Angelin (Iconogr. Plate 28, Fig. 14); they are a little compressed at the sides, and are directed upwards and outwards. The trigonal pieces also rise into spiniform partitions, but these are shorter and smaller generally. Structure of the arms unknown.

*Horizon and Locality.* — Niagara group; Racine, Wisc., and Chicago, Ills.

*Types* in the N. Y. State Cabinet of Natural History at Albany.

*Remarks.* — The large collections of Mr. Thomas A. Greene of Milwaukee, and Mr. W. C. Egan of Chicago, contain a few specimens in which the dorsal cup is unusually expanded at the arm bases, less broadly truncated at the bottom, and the first costals somewhat larger; while otherwise agreeing with the rest of the specimens. These specimens do not agree with *C. cornutus*, var. *excavatus* Hall, which was not accepted by Whitfield, and we think that both these forms may be regarded as variations of *C. cornutus*.

### (?) **Callicrinus ramifer** F. Roemer.

1860. *Eucalyptocrinus ramifer* — Roemer Silur. Fauna West. Tenn., p. 51, Plate 4, Figs. 4*a*, *b*, *c*.
1885. *Eucalyptocrinus ramifer* — W. and Sp.; Revision Palæocr., Part III., p. 134.

This species is only known from the general form of its dorsal cup, and there is some doubt whether it should be referred to *Callicrinus* or to a new genus. It differs from the other species of that genus in the size of its basals, which are largely represented at the outer walls of the dorsal cup; moreover the orientation of the pentangular basal concavity is reversed, its angles being directed interradially, while they are radial in *C. cornutus* and other species. Dorsal cup nearly as high as wide, the base broadly truncated, its lower margin a little projecting laterally and forming a sharp edge; the sides gently curving to near the top, where they slightly contract. The suture lines are not shown in Roemer's type, but we can see from a fragmentary specimen in our own collection that the basals are very irregular; three of them are quadrangular, the fourth pentangular and larger, the latter broadly truncated and supporting a radial, which is smaller than the others and slightly convex at the lower face. The other three basals, which rest each one between two radials, are distinctly angular below. First costals quadrangular, once and a half as wide as long; the second considerably larger and pentangular, the distichals arching over its upper angle. First interbrachial large, decagonal, almost as wide as long. The plates thin, and, so far as observed, without surface markings, except obscure angularities following the median lines of the radials and brachials, and a small conical elevation within the middle of the first interbrachial.

*Horizon and Locality.* — Niagara group; Wayne and Decatur Cos., Tenn.

*Type* in the Mineralogical Museum, at Breslau, Germany.

*Remarks.* — If this is a true *Callicrinus*, it differs from all the other species of this country, as well as of Europe, in the large size of its basals, which in no other species are exposed along the sides of the cup.