Early Silurian Camerate Crinoids of Eastern Iowa

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Early Silurian Camerate Crinoids of Eastern Iowa

BRIAN J. WITZKE and HARRELL L. STRIMPLE

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Large and diverse Lower Silurian (late Llandovery) camerate crinoid faunas from the Hopkinton Dolomite of eastern Iowa form the basis of the present study and partially fill the long gap between previously known Late Ordovician and Middle Silurian (Wenlockian) faunas. Taxa are considered in detail up to and including the species Luxocrinus simplex, Dimerocrinites (Dimerocrinites) sculptus, D. (D.) hopkintonensis, Allozygocrinus dubuquensis, Pregazacrinus hemisphericus, Carpocrinus bodei, Bolocrinus globosus, B. deflatus, Thomasocrinus cylindrica, Krinocrinus inflatus, Macrozygocrinus compressus, M. vermiculatus, Allozygocrinus ornatus, Marsupiocrinus (Amarsupiocrinus) primaevus, Archaeocalyptocrinus nodosus, A. iowensis, and Theleproktocrinus davidsoni.

Stratigraphy of the Hopkinton Dolomite has been summarized elsewhere and is not extensively discussed. New information on the Early Silurian evolutionary radiation.


INTRODUCTION

EVOLUTION OF THE SILURIAN CAMERATE CRINOIDS

ACKNOWLEDGEMENTS

TERMINOLOGY

REPOSITORIES

SYSTEMATIC PALEONTOLOGY

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Subclass CAMERATA Wachsmuth & Springer, 1885

Order DIPLOBATHRIDA Moore & Laudon, 1943

Suborder EUDIPLOBATHRINA Ubaghs, 1953

Superfamily RHODOCRINITACEA Roemer, 1855

Family RHODOCRINITIDAE Bassler, 1938

Genus RHODOCRINITES Phillips, 1839

Subgenus RHODOCRINITES (DIMEROCRINITES) Phillips, 1839

D. (D.) sculptus n. sp.

D. (D.) hopkintonensis n. sp.

Subgenus DIMEROCRINITES (EU CRINUS) Angelin, 1878

D. (E.) sp.

Family DIMERO CRINITIDAE Bassler, 1938

Genus DIMERO CRINITES Phillips, 1839

Subgenus DIMERO CRINITES (DIMERO CRINITES) Phillips, 1839

D. (D.) sculptus n. sp.

D. (D.) hopkintonensis n. sp.

Subgenus DIMERO CRINITES (EU CRINUS) Angelin, 1878

D. (E.) sp.

Family LAMPTER CRINITIDAE Bather, 1899

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INTRODUCTION

Significant advances in camerate crinoid evolution occurred during the interval separating known Late Ordovician and Middle Silurian (Wenlock-Llandovery) echinoderm faunas. The discovery of diverse Early Silurian (late Llandovery) camerate faunas in the Hopkinton Dolomite of eastern Iowa partially fills this long gap in the geologic record. Of the more than 2700 generically identifiable echinoderm fossils examined from the Hopkinton Dolomite during the course of this study, more than 75% of the individuals are camerate cnidoids. Additionally, specimens of inadunate and flexible cnidoids, rhombiferan and diploporan cystoids, blastoids, eocrinoids, and paracrinoids are also noted (Witzke, 1976; Witzke, Frest and Strimple, 1979; Frest, Strimple and Witzke, 1980). Preservation of the Hopkinton cnidoids as internal and external molds is generally poor, although the critical plating arrangement of the dorsal cups is preserved on many of the specimens.

The stratigraphy of the Hopkinton Dolomite is summarized in reports by Johnson (1975, 1977) and Witzke (1978, 1980) whose stratigraphic nomenclature largely follows Calvin and Bain (1900). Echinoderm debris is scattered to abundant throughout most of the Hopkinton Dolomite, most commonly as molds of disarticulated plates and columnals or dolomitized echinoderm wackestone to packstone textures. However, articulated camerate cnidoid cups have been noted in only two stratigraphic intervals within the formation. The stratigraphically lower interval, the “Cyclocrinites beds” of Johnson (1975), has produced a variety of patellocrinid and patellocrinid-derived taxa and the oldest representatives of several camerate cnidoid families. The “Cyclocrinites beds” are considered by Johnson (1975, 1977) to be of mid Late Llandovery age (C3-C4). Identifiable echinoderm remains are scattered to abundant in this stratigraphic interval, and brachiopods (especially globular Pentamerus and Stricklandia), molluscan fossils (gastrapods, nautiloids), and Cyclocrinoids (a green alga) are especially prominent.

The “Cyrtia beds” have yielded the greatest abundance and diversity of cnidoids in the Hopkinton, and this interval is probably C5-C6 late Llandovery in age (Johnson, 1975, 1977; Witzke, 1978). The “Cyrtia beds” include dense, micritic, fossiliferous dolomites with scattered to abundant echinoderm, brachiopod, and bryozoan fossils and porous very crinoidal dolomites. A zone of biorthogonal (reef) buildups and flat-lying inter-reef rocks occurs beneath the “Cyrtia beds,” and coarse cnidoidal packstones may bury these bioherms (Philoix, 1970) in a stratigraphic position equivalent to the lower “Cyrtia beds.”

The “Cyrtia beds” are separated from the overlying “Pentameroides beds” primarily on the basis of fossils, and together the “Cyrtia-Pentameroides beds” form a single rock-stratigraphic unit (Witzke, 1978, 1980). Disarticulated echinoderm debris is volumetrically more important than the articulated cnidoidal cups which are scattered to abundant throughout much of the interval.

EVOLUTION OF THE SILURIAN CAMERATE CNIDOIDS

An explosive evolutionary radiation within the camerate cnidoid groups, coinciding with the spread of extensive intracontinental carbonate shelf environments during a generally transgressive marine sequence, occurred during the Llandovery (Early Silurian) in North America (Witzke, Frest, and Strimple, 1979). Many camerate cnidoid genera and families first appeared at that time, and these new taxa formed the root stocks from which many characteristic Wenlockian-Ludlovian (late Silurian) taxa, both endemic and cosmopolitan forms, arose. The Hopkinton cnidoid faunas fill a critical gap in the evolutionary history of the camerate, and little supplemental information of Llandovery cnidoid evolution is currently available (ibid.: Brower, 1975). A study of the Early Silurian camerate cnidoids from Iowa has necessitated several revisions in the proposed camerate phylogenies of Moore and Laudon (1943) and Ubaghs (1978).

Primitive dimerocrinid, patellocrinid, molocrinid, rhodocrinid, and tanaocrinid forms filled the primary stocks from which most Silurian camerate cnidoids were originally derived. These camerate stocks are represented in Late Ordovician faunas of the North American continental interior. Latest Ordovician carbonate units in Missouri (Girardeau, Noix, Cyrene) are among the best sources of these ancestral camarates (e.g. Brower, 1973).

The camerate cnidoids are divisible into monocryclic forms with only a single circle of plates (the basals) below the radials and dicyclic forms with two circles of plates (basals, infrabasals) below the radials. The monocryclic—dicyclic schism arose early in the evolution of the camarates and, in most cases, remains of primary phylogenic significance (Warn, 1975). The Hopkinton fauna includes several dicyclic camerate cnidoid groups (Rhodocrinidae, Dimerocrinidae, Lampterocrinidae, Gazacrinidae). Two rhodocrinid taxa are meagerly represented in the Hopkinton collections, and both of these taxa represent extremes in dorsal cup simplification for the family. An unnamed rhodocrinid, apparently derived from a form like Asactocrinus (Late Ordovician, Illinois), is characterized by the complete expulsion of the interbrachs in one or more interrays allowing some of the radials and primibrachs to join. This extreme condition is never again repeated in the long history of the dicyclic camarates. Luxocrinus has a dorsal cup with one fixed primibrach per ray and a single interbrach per interray producing the simplest plate configuration of any known rhodocrinid. No additional rhodocrinid taxa are currently known from the Hopkinton Dolomite, and the origins of later Silurian rhodocrinids and archaeocrinid-derived taxa remains poorly understood. However, the ultra-simplified cup configuration of the known Hopkinton rhodocrinids suggests that major and apparently rapid evolutionary modifications arose within the Early Silurian rhodocrinid groups at a time when other camerate groups were also undergoing evolutionary radiation.

Several primitive dimerocrinid taxa (3 species of Ptychocrinus) are known from Late Ordovician faunas of North America, and these forms provided the ancestral stock from which several major camerate groups radiated in the Llandovery seas of North America. The development of biserial arms from the Ptychocrinus stocks would produce forms assignable to Dimerocrinidae, a cosmopolitan genus throughout much of the Silurian, or Eudimerocrinidae. Dimerocrinidae forms the central stock from which three short-lived North American endemic camerate families evolved. The development of an anal tube, as in D. hopkintonensis, along with the posterior bulging of the calcyx produced the highly successful endemic Lampterocrinidae. The expulsion of distal interbrachs and compression of the fixed brachials in a dimerocrinid stock produced the North American endemic Gazacrinidae. The radiation of the gazacrinids and lampterocrinids probably occurred in the late Llandovery (about C4). In elastic deposits of similar age in Scotland and New York (Brower, 1975; Brett, 1978) the still persistent, though archaic, Ptychocrinus lines are noted. Another group, the nycocrinids, has been noted only in Ludlovian deposits of Tennessee and was probably derived from the gazacrinids by expulsion of the interbrachs and fixed brachials allowing the radials to come in contact all around (Moore and Laudon, 1943, p. 84). An unusual additional form in the Hopkinton, Alloxyzocrinus, may be related to the dimerocrinids and is comparable to probable dimerocrinids in Scotland (Brower, 1975).

Abundant monocryclic camerate cnidoids are noted in the Hopkinton Dolomite (Periechoocrinidae, Carpocrinidae, Patelliocrinidae, Marsupiocrinidae, Euclaeyptocrinidae, Hapalocrinidae, and Himeocrinidae), and, excluding the patelliocrinids and possibly the pericrinids, include the oldest and most primitive members of the included families. The tanaocrinid stock, as represented by Compsocrinus, is present in the Late Ordovician faunas of North America, and the
The eucalyptocrinitids, previously thought to have been derived from a clonocrinit-like ancestor (Moore and Laudon, 1943, p. 99; Ubaghs, 1978, p. 286) are believed, instead, to have been derived directly from a patelliocrinid stock. Ancestral eucalyptocrinitids (*Archaeprocrinites*) are noted in mid late Llandovery strata in Iowa, and the conical base of the dorsal cup is most reminiscent of the patelliocrinitids. The invagination of the base and the development of tegmen partitions accompanied the C5-C6 Late Llandovery evolution of two highly successful cosmopolitan (Wenlockian, Ludlovian) genera, *Eucalyptocrinites* and *Callicrinites*. Ray simplification of *Callicrinites* produced *Chicagocrinus* in the Wenlockian. The Clonocrinitidae was probably derived directly from a patelliocrinid stock (Moore and Laudon, 1943, p. 98), although the evolution was apparently independent of the eucalyptocrinitids. A European endemic family, the Stelidiocrinidae, was probably derived from a European patelliocrinid stock sometime in the late Llandovery or Wenlockian.

The Hopkinton Dolomite has produced the oldest known hapalocrinid, *Theleproktoocrinus*. This ancestral hapalocrinid appears to have been derived from a patelliocrinid stock by enlargement of the radials, expulsion of the interbrachs onto the tegmen, and expulsion of the fixed secundibrachs from the cup. Further expulsion of the primibrachs and the development of large oral plates distinguishes most younger hapalocrinids from *Theleproktoocrinus*. A North American endemic group, the himeocrinitids, were derived from primitive hapalocrinids before the end of the Llandovery. The platocrinitids appeared later in the Silurian, and were probably derived from a modified hapalocrinid.

The late Llandovery was a time of unprecedented experimentation among many known camerate crinoid groups, and extremes in camerate dorsal cup simplification and tegmen specialization are noted. The evolutionary relationships among the camerate crinoid groups inferred by Moore and Laudon (1943) and modified or confirmed in this and other studies are summarized in Figure 1. As interpreted by Ubaghs (1978, p. 286), his illustrated evolutionary trends in the Camerata are decidedly gradualistic in the derivation of most higher taxa. Ubaghs derives most Silurian families from remote and unknown ancestors in the Lower, Middle and Upper Ordovician as suggested by his illustrations. A light of changing ideas about evolutionary theory and the possibility of geologically rapid evolutionary events (considered viable by many paleontologists), gradualistic inferences imposed upon phylogenies may conceal evolutionary events such as radiations. For example, Ubaghs (ibid.) infers the derivation of the carpocrinids from an unknown tanaocrinit in the Lower Ordovician, whereas this study derives the carpocrinids, based on transitional features exhibited on Hopkinton specimens, directly from the morphologically similar periechocrinids.

The dramatic evolutionary expansion among many of the camerate crinoid groups that occurred during the late Llandovery seems to coincide with the expansion of carbonate environments as seas inundated the North American continental interior. Differentiation of the existing Late Ordovician carbonate-dwelling crinoids occurred as new niches for benthic suspension-feeding groups were realized in the expanding carbonate environments. Some of the groups, possibly due to restricted larval dispersal potentials, remained endemic to a given carbonate shelf throughout the Silurian (Witzke, Frest and Strimple, 1979). The maximum diversification of these echiocrinid groups was reached in the Wenlockian. The Silurian suspension-feeding echiocrinid groups became well adapted, not only in many level-bottom paleocommunities, but also as dominant elements of many reef and reef-associated paleocommunities. A general marine regression, apparently beginning in the late Wenlockian and continuing through the remainder of the Silurian, marked a time of crisis among many of the suspension-feeding echinoderm groups. The surviving echiocrinid groups show little further diversification until the Devonian.

Unlike the replacement of North American endemic brachiopods by...
Old World groups at the beginning of the Silurian (Sheehan, 1975, p. 206), "the Silurian echinoderm radiation has one of its major focal points in the Ordovician faunas of North America" (Witzke, Frese, and Strimple, 1979, p. 127). Speciation in the diversifying benthic echinoderm groups probably occurred within the confines of the epicontinental seas. Many of the echinoderm faunal elements characteristic of the continental interior are notably lacking from continental margin ("onshore") deposits and the preserved lineages of most Silurian echinoderm groups are noted only in carbonate deposits of the continental interior (e.g., Hopkinton Dolomite). The contention that "the opportunities for speciation appear to have been in the onshore areas" (Eldredge, 1974, p. 544) may be an incorrect generalization for benthic invertebrate groups. During transgressive marine sequences many opportunities for speciation and migration should be available within the confines of the epicontinental seas, especially as "endemic" reef and level-bottom environments are created. Marine regressions, on the other hand, would be times of crisis among specialized benthic invertebrate groups restricted to niches on the retreating carbonate shelf.

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TERMINOLOGY

The terminology, nomenclature, and diagnoses of taxa above the generic rank utilized in this study are from the Treatise on Invertebrate Paleontology, Part T (Univ. Kansas Press), unless otherwise noted.

REPOSITORIES

All specimens examined during the course of this study are repositored in the University of Iowa, Iowa City, Department of Geology collections (SUI) or the Field Museum, Chicago, Walker Museum and other University of Chicago collections (UC). Locality numbers are listed in the Appendix.

SYSTEMATIC PALEONTOLOGY

Class CRINOIDEA Miller, 1821
Subclass CAMERATA Wachsmuth & Springer, 1885
Order DIPLOBATHRIDA Moore & Laudon, 1943
Suborder EUDEIPLOBATHRINA Ubaghs, 1953
Superfamily RHODOCRINITACEA Roemer, 1855

Diagnosis: Radials generally separated from each other by interbrachs which adjoin basals, although radial circlot may be partly adjoined. Discussion: The superfamilial diagnosis has been emended from Ubaghs (1978, p. 4-10) to include forms that may have the radial circlot partly adjoined. Atactocrinus, some Lyriocrinus, and an undetermined rhodocrinitid from the Hopkinton Dolomite are known to possess adjoined radial plates. The trend toward closure of the radial circlot in certain rhodocrinitaceans led to the development of the dimerocrinitaceans.

Fig. 1. Inferred phylogeny of the Late Ordovician through Lower Devonian camerate crinoid families. Width of branches reflects relative abundance or diversity of each family in known collections. Time scale on left side; Llandoverian through Pridolian represents the Silurian. Right side shows probable eustatic sea level curve (R = regressive or shallowing trend, T = transgressive or deepening trend).
Family RHODOCRINITIDAE Bassler, 1938

Discussion: 'Ubaghs' (1978) familial diagnosis should be modified to include forms with partly adjoined radial circlets.

Rhodocrinitid sp.
Plate 1, Fig. 1; Text-fig. 2

Description: Dorsal cup subglobose, wider than high. Infrabasal circket pentagonal; basals large, adjoining all around; larger BB hexagonal; smaller BB pentagonal, aligned with adjoining RR plate sutures. Radial circket partly adjoined, partly separated; RR wider than high, pentagonal or hexagonal. Single large primibrach per ray bears arm facets; primibrachs adjoin in those rays in which RR adjoin, otherwise separated by interbrach. Interbrachs present only above hexagonal BB; first interbrach large, heptagonal, bearing two plates in next range that are largely incorporated into tegmen. Two arms per ray. SUI 42278 measures 8 mm high x 10 mm wide.

Fig. 2. Rhodocrinitid plate diagrams (RR black). A) Early Silurian rhodocrinitid, Hopkinton Dolo., Iowa. B) Late Ordovician Atactocrinus, Illinois (from Weller, 1916).

Discussion: A single specimen of a very unusual rhodocrinitid from the "Cyclocrinites beds" reveals the radials partly adjoined and partly separated. The specimen may be an abnormal representative of an undetermined rhodocrinitid, although its close resemblance to the Late Ordovician (Illinois) Atactocrinus would tend to preclude such an interpretation. Exclusion of the distal cup plates, particularly the interbrachs above the adjoined RR, in Atactocrinus (Weller, 1916) would produce a form like SUI 42278. The exclusion of the interbrachs above the pentagonal BB would also allow the primibrachs to adjoin in that position. No other camerate crinoid is known in which the primibrachs from adjacent rays adjoin, and when more material becomes available a new genus will probably be warranted for this unusual rhodocrinitid. Alternatively, the form may represent an abnormally developed rhodocrinitid.

Material: SUI 42278
Horizon and Locality: "Cyclocrinites beds;" Locality 28.

Genus LUXOCRINUS n. gen.

Type species: Luxocrinus simplex n. sp.

Diagnosis: Calyx low, bowl-shaped; infrabasals small, in basal concavity, restricted to area of column facet; single large interbrach present above each basal; arms branch from first primibrach; ambulacra form star-like shape internally.

Discussion: Luxocrinus represents the extreme in dorsal cup simplification noted in the superfamily. Although the type species is represented by poorly preserved material, available specimens illustrate the simplified dorsal cup plate arrangement. The presence of a single interbrach per interray and a single primibrach per ray readily distinguishes Luxocrinus from all other rhodocrinitaceans. Springer (1926, p. 24) discussed the proximal portion of the cup of an indeterminate rhodocrinitid from the Laurel Limestone (Wenlockian); it differs from Luxocrinus in lacking a basal concavity and in having large iBB. Emperocrinus (Laurel Ls.) resembles Luxocrinus in possessing a single interbrach per interray and small iBB but differs in having depressed interrays and well-developed rays (2 IBr and II Br). Luxocrinus most closely resembles the Middle Ordovician (Newfoundland) Trichinocrinus in possessing small iBB at the bottom of a basal concavity and a single large iBr per interray (Moore & Laudon, 1943a), but Trichinocrinus differs primarily in having two fixed primibrachs per ray and in general cup shape and ornamentation.

Derivation of name: Lux, the quarry from which the type species was collected.

Luxocrinus simplex n. sp.
Plate 1, Figs. 2-5; Text-fig. 3

Fig. 3. Plate diagram of Luxocrinus simplex. RR black.

Description: Dorsal cup low, bowl-shaped, infrabasals small, restricted to column facet at bottom of basal concavity. Basal concavity incorporates proximal portion of BB; basals large, hexagonal. Radials pentagonal, similar in size to BB; single primibrach per ray, hexagonal, distal margin curved onto tegmen. Proximal margin of BB in contact with single hexagonal interbrach, the largest plate in cup; iBr in contact with large plate at lateral margin of tegmen. Tegmen plate structure unknown; five ambulacral tracts preserved internally (and externally?) forming star-like shape. Column and arms unknown. Holotype measure 6 mm high x 10 mm wide; largest paratype measures 7 mm high x 12 mm wide.

Derivation of name: Simplex refers to the greatly simplified cup plate.
configuration.

Holotype: SUI 42283.

Material: Four paratypes are designated SUI 42284; 7 additional specimens, SUI 42285.

Horizon and Locality: "Cyrtia beds;" Locality 15.

Superfamily DIMEROCRINITACEA Zittel, 1879

Diagnosis: Radials generally adjoining except on posterior side; in-traspecific variation is occasionally noted in which the radials may be separated or adjoining.

Discussion: Ubags (1978) divided the Eudiplobathrina into two super-familial groupings, the Rhodocrinitacea and Dimerocrinitacea, based on whether or not the radials are separated from each other by interposing interbrachs (interradials), although variation in this criterion was noted (ibid., p. 287). Moore and Laudon (1943, p. 82) monophyleti-cally derived all dicyclic camarates with adjoining radials from Psychocrinus. However, the shifting of the iBr1 higher in the cup allowing the RR to come in lateral contact could have arisen in several independent lineages, and this general trend is evident in three appar-ently separate ptychocrinid lines. Several dimerocrinitacean taxa can exhibit a radial plate configuration like the rhodocrinitaceans, and these forms are discussed below.

One species included in the Lampterocrinidae, Siphonocrinus nobilis, can exhibit features characteristic of both superfamilies; some S. nobilis have the RR in lateral contact, others reveal the RR separated by the first interbrachs. Weller (1900, p. 88) recognized the problem and questioned whether the “Thysanocrinidae [= Dimerocrinitacea] and Rhodocrinidae [= Rhodocrinitacea] should be considered as dis-tinct.” Specimens of Dimerocrinites icosidactylus (Wenlock, Eng-land) are also known in which the RR may be separated (Brower, 1973, pp. 446, 451). Likewise, Griphocrinus, a genus included in the Dimerocrinitidae, have all or a variable number of radials sepa-rated by interposing interbrachs (Kirk, 1945, p. 350; Breimer, 1962, p. 18). The separation of the radial plates in these mentioned taxa is probably a resultant feature related to the evolution of a widening dorsal cup. Alternatively, these forms may indicate a polyphyletic origin of the Dimerocrinitacea from several nonptychocrinid stocks, although this remains to be seen. Two genera included in the Rhodocrinitacea, Atactocrinus and Lyricrinites, may also have partly separated, partly adjoined RR circlcts (Breimer, 1962, p. 18). The possible polyphyletic origins of the Dimerocrinitacea is further discussed under the Dimeroc-rinitidae and Lampterocrinidae.

Although confusing variation in the radial cirlet of Siphonocrinus nobilis, Dimerocrinites icosidactylus and Griphocrinus places the distinc-tion of the Dimerocrinitacea from the Rhodocrinitacea in doubt, Ubags’ (1978) superfamilial distinction is readily usable for most dicyclic camarate groups. Since forms assignable to the Dimerocrinitacea gave rise to forms assignable to the Dimerocrinitacea, it should not be surprising to find a few “problem” species exhibiting characteristics of both superfamilies. Classification problems of this type are not unusual in the crinoids as Wachsmuth and Springer (1897, p. 262) noted in the Rhodocrinitidea: “Departures ... 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.”

Family DIMEROCRINITIDAE Bassler, 1938

Diagnosis: Median ray ridges present in primitive members; radials generally adjoining except on posterior side, although RR may be separated in lateral interrays; interbrachs well developed, regular, may be depressed, connecting with tegmen, iBr1 typically followed by two plates; primal supports 3 plates in next range, often with sagittal series of extra plates leading to anus; arms simple or branching, unise­rial, biserial, or compound; stem round to subelliptic.

Discussion: Psychocrinus was not regarded by Moore and Laudon (1943, p. 83) as a dimerocrinitid because of its uniserial arms and was classified in a separate family, the Psychocrinitidae. Ubags (1978) and Brower (1973) regard Psychocrinus as the oldest genus included in the Dimerocrinitidae and modified the familial diagnosis to include both uniserially and biserially armed forms. Psychocrinus, a genus endemic to North America in the Late Ordovician, includes three “highly divergent” species. “By the standards applied to other Ordovician camarate families, the three crinoids would be placed within different genera” (Brower, 1973, p. 445). By the development of biserial arms and a competent tegmen in these three ptychocrinid lines most, if not all, of the typical biserially-armed dimerocrinitids arose. Psychocrinus probably arose from uniserially armed “archaeocrinids” as the distal movement of the iBr1 allowed the RR to adjoin. It is the closing of the RR cirlet that distinguishes Psychocrinus from similar “archaeocrinids,” although the ptychocrinus dorsal cup plate configuration may actually have arisen independently in two or more converging lineages. The three Ordovician species of Psychocrinus do not differ dramatically from each other in general cup characteristics, although the three different arm types are fundamentally different; 10-armed unbranched forms (P. fimbriatus), 20-armed unbranched forms (P. parvus), and branching forms in which the rays are fixed only up through part of the iBr1 series, (P. splendidus). P. fimbriatus probably arose directly from an “archaeocrinid” like Raphanocrinus subnodosus.

The Dimerocrinitidae can be conveniently grouped into three differ­ent categories based on the nature of the arms, a feature of primary significance for most genera contained in the family. Group 1, typified by Eudimocrinus, is characterized by forms with biserial branching arms (may branch 1, 2, or 3 times). Three genera are included in this group: Eudimocrinus, Ambicocrinus, and Griphocrinus. Group 1 may be polyphyletic; several possible origins are proposed. First, it may have arisen directly from an archaeocrinid with biserial branching arms. Alternatively the development of biserial arms from the uniserial branching arms of the Psychocrinus splendidus stock would have produced Group 1 characteristics. The development of branching arms from the Group 2 stock is a third possibility. Lastly, the lateral adjoin­ing of the RR from a biserially-armed rhodocrinitacean stock would also have achieved Group 1 characteristics; Griphocrinus, with its variably separated or adjoined RR, may have arisen in this manner. The discovery of the archaic line of Group 1 ptychocrinids in Llandoveryan clastic environments of New York (P. medinisinus Brett, 1978) contrasts with the interior carbonate platform where a greater diversity of more advanced Group 1 dimerocrinitids are noted.

Anthemocrinus, placed in the Anthemocrinidae of the Rhodo­crinitacea, closely resembles Group 1 dimerocrinitids except that only one primibrach per ray and 4 BB are present. Macarocrinus, a Lower Devonian form with branching uniserial arms, is included in the Di­merocrinitidae; a distant but plausible ancestor of Macarocrinus would be uniserially-armed forms such as the Lower Silurian Psychocrinus medinisinus. Nyctocrinus, a Silurian form with a completely closed RR cirlet and branching biserial arms, probably arose from a form like Gazacrinus (derived from Group 2 dimerocrinitids).

Group 2, characterized by ten simple biserial arms, includes a number of Dimerocrinites, herein called D. (Dimerocrinites), and possibly Cyphocrinus. Ten-armed Dimerocrinites (Dimerocrinites) include D. decadactylus (Wenlock Ls., Eng.), D. brachiatus (Lockport Ls., N.Y.), D. liliformis (ibid.), D. occidentalis (Waldron Sh., Ind.), D. robustus (ibid.), D. prainspina (Boggspring Fm., Tenn.), D. mil­liganei (ibid.), D. roemeri (ibid.), D. elongata (Juniper Fm., Anticosti), D. longimanus (Silurian, Gotland), D. hopkintonensis (Hopkinton
Dolo., Iowa). D. sculpus (ibid.), D. eugeniust (Ridgeyl Sa., Md.); questionably included are D. campanulatus (Silurian, Ill.), D. egani (Racine Dolo., Ill.), and D. pentangularis (Racine Dolo., Ill., Wis.). The most probable origin of Group 2 dimerocrinitids is by development of biserial arms in the uniserially-armed Ptychocrinus fimbriatus stock. Alternatively, some of the Group 2 dimerocrinitids could have been derived from the Group 3 stock by loss of some arms. A third possibility was proposed by Moore and Laudon (1943, p. 84) for the origin of Cyphocrinus, a broad-cupped form, from the Group 1 dimerocrinitid stock; the loss of arm-branching in the Eudimerocrinites stock could have derived some Dimerocrinites (Dimerocrinites) in a similar manner. Lyriocrinus, a member of the Rhodocrinitidae with ten simple biserial arms, could conceivably be related to Group 2 dimerocrinitids if the RR circle in the two families can be variably open or closed. The archaic 10-armed pychocrinite stock persisted into the late Llandovery as evidenced by the discovery of Ptychocrinus longobrcialis in clastic deposits of Scotland (Brower, 1975).

Group 3 dimerocrinitids are represented by Dimerocrinites with twenty biserial arms branching on the IIb (rarely IIb or IIb) herein termed D. (Eucrinus). Included are D. laevis (Silurian, Goltland), D. interradialis (ibid.), D. quinquangularis (ibid.), D. speciosus (ibid.), D. nodabasis (Brownstown Fm., Tenn.). D. lockportensis (Lockport Ls., N.Y.), D. whitfieldi (M. Dev., N.Y.), and D. sp. (Hopkinton Dolo., Iowa). D. icosadactylus (Wenlock Ls., Eng.) is an irregular Group 3 dimerocrinitid with three or four arms per ray. Dimerocrinites (Eucrinus) most likely originated from the simple uniserial 20-armed Pychocrinus parvus stock, although the insertion of fixed tertibrachs in each ray of a Dimerocrinites (Dimerocrinites) would achieve similar results. Dimerocrinites pentlandicus from the late Llandovery of Scotland is questionably assigned to the genus by Brower (1975), and this species was probably derived from earlier 20-armed Pychocrinus. The development of a zygodiplobathrid-like base in D. pentlandicus is divergent from the general trend of dimerocrinitid evolution (also see Alleyocrinus discussion), and probably represents a fourth group of dimerocrinitids independent of normal 20-armed stocks in the Lower Silurian.

Genus DIMEROCRINITES Phillips, 1839

Type species: Dimerocrinites decadactylus; Roemer, 1855, SD. 

Diagnosis: Calyx conical to globose; plates smooth to ornamented; median ray ridges generally present; interray areas depressed; series of smooth or ridged anal plates often present; tegmen commonly but not always lacks anal tube; arms biserial, 2 or 4 per ray (rarely 3), generally free above third through sixth brachial; stem circular (Weller, 1900; Ubaghs, 1978).

Discussion: Brower (1973, p. 446) noted that "Dimerocrinites is a highly heterogeneous genus in dire need of revision," and an attempt has been made at subdividing the genus into two simpler taxonomic units. Two distinct groups are included in Dimerocrinites, 10-armed forms and 20-armed forms. These two groups may each have been derived along independent lines. Most described species of Dimerocrinites can easily be assigned to either of the two groups contained in the genus; these two taxonomic units are herein assigned subgeneric rank. However, the subgeneric placement of several species of Dimerocrinites remains uncertain: D. aculeatus, D. canaliculatus (both known only from isolated arms), and D. vagans. Brower (1973, p. 451) believed that D. vagans was monocious, Foerste (1919, p. 13) believed that D. vagans might be a dicyclic form with greatly reduced infrabranchals (not preserved) in which case it would probably represent an exceptionally flat-cupped dimerocrinitid (RR still adjoining regardless of the flattening). Angelin (1878, pl. 6, fig. 7) illustrated both 10- and 20-armed D. ornatus from Gotland, and it is not known which of the two forms is diagnostic of the species.

Subgenus DIMEROCRINITES (DIMEROCRINITES) Phillips, 1839

Diagnosis: Dimerocrinites with ten simple biserial arms.

Type species: D. decadactylus.


Discussion: The type species of Dimerocrinites (Dimerocrinites) has quadrangular IBrl and pentagonal or heptagonal IAx. Several other species of the subgenus, D. planus, D. egani, D. roemeri, D. pentangularis, have variably shaped (4-, 5-, or 6-sided) IBrl. The remainder of the species included in the subgenus have hexagonal IBrl. Variably shaped IAx (5-, 6-, or 7-sided) are noted in the type species, D. planus, D. milliganae, D. campanulatus, and D. egani. The remainder of the species in the subgenus have pentagonal IAx. D. egani may be a juvenile of D. pentangularis (Weller, 1900, p. 75). Hall's (1852) genera, Thysanocrinus and Glyptaster, are synonymous with Dimerocrinites (Dimerocrinites). Angelin (1878) made a generic distinction between the ten- and twenty-armed dimerocrinitids of Gotland labeling the ten-armed forms Harmocrinus, also synonymous with D. (D). D. (D), probably originated in North America and spread to Europe (Gotland, England) by Wenlockian time.

Dimerocrinites (Dimerocrinites) sculpus n. sp.

Plate 1, Figs. 8-14

Diagnosis: Calyx obpyramidal, decidedly pentagonal in cross-section;

Note: all specimens on plates 1-5 are internal molds unless otherwise indicated; all specimens are coated with ammonium chloride sublimate; plate sutures are artificially enhanced unless otherwise indicated.


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EARLY SILURIAN CAMERATE CRINOIDS OF EASTERN IOWA

Witzke and Strimple: Early Silurian Camerate Crinoids of Eastern Iowa

Published by UNI ScholarWorks, 1981
sutures between infrabasals are elevated into rounded, radiating ridges on internal molds forming a star-shaped calyx base; tegmen flat or nearly so, although anal tube may be developed; surface of plates decorated with a series of parallel ridges adjoining the centers of all plates dividing the surface into concentrically-banded triangular areas. 

**Description:** Calyx obovoidal, decidedly pentagonal in cross-section. Infrabasals small, triangular, together forming a pentagonal basal disc. Basals pentagonal, except hexagonal posterior basal. Radials large, heptagonal in A, B, E rays, hexagonal in C, D rays, adjoining all around except on posterior side; primibrachs hexagonal; primaxils pentagonal. Secundibrachs hexagonal, 4 II Br per half ray incorporated into cup. Interrays depressed; first interbrach large, supporting 2 plates in next range, one heptagonal and one hexagonal. Two third range interbrachs developed, one heptagonal and one pentagonal. Interrays probably developed to fifth range, 1:2:2:2:1. First intersecundibrachs hexagonal, similar in size to secundibrachs, bearing two plates in second range and one in the third range. Primal basal, resting on posterior basal. Posterior interray differentiated, three hexagonal plates above primal; sagittal series of unridged anal plates present. Tegmen flat or nearly so; ambulacra branch once, leading to ten arm facets; ambulacrals and interambulacrals developed (SUI 31766, 31708). Anus subcentral, may be elevated (SUI 31708). Sutures between infrabasals are elevated into rounded, radiating ridges on internal molds forming a star-shaped pattern; median ridges bifurcate at primaxil continuing into secundibrach series to arm facets. Surface of plates decorated with a series of distinct parallel ridges adjoining the centers of all cup plates and dividing the surface of the plates into concentrically-banded triangular areas. Calyx measures (height x width): 8 mm x 9.3 mm to 46 mm x 46 mm. Variation in calyx shape, height/width ratio, 0.85-1.05.

**Discussion:** D. (D.) sculptus most closely resembles D. (D.) pentangularis of the Racine Dolomite but differs in having a generally squatter cup, a distinct star-shaped pattern on internal molds along the infrabasal sutures, and in its ornately sculptured plates (D. pentangularis has smooth plates; Weller, 1900, p. 71). One specimen, SUI 39965, differs from all other specimens of D. (D.) sculptus in having a high-vaulted tegmen with an anal tube developed; other specimens preserving the oral surface (SUI 31744, 31766) exhibit a nearly flat tegmen with no anal tube. SUI 39965 exhibits a dorsal cup identical with D. (D.) sculptus; the development of an anal tube is probably atypical of the species. Some specimens (e.g., SUI 31708) exhibit a slightly protrubent anus somewhat intermediate in form between the flat-tegmened and high-tegmened samples.

**Derivation of name:** Sculptus refers to the sculptured ridges on the plate surface (Rowser, 1932, p. 77).

**Holotype:** SUI 31767 (Locality 2).

**Material:** Seven paratypes are designated SUI 31768 (4) and 31766 (3). One-hundred seventeen additional specimens are numbered SUI 31701 (2), 31702 (15), 31703 (2, internal, external), 31704 (int., ext.), 31706 (int., ext.), 31707, 31708 (39), 31710 (2), 31715 (3), 31716, 31744 (2), 39963 (10), 39964 (21), 39965 (3), 39966 (2), 39967, 39968 (11). Variation in the closely-spaced arm facets, excluded II Br, and extreme laterally bifurcating ambulacra of D. (D.) hopkintonensis. Enlargement of the basal, development of a more elongate anal tube, loss of arms, and bulging of the posterior interray in a form like D. (D.) hopkintonensis would produce forms assignable to Lamperocrinus.

**Horizon and Locality:** “Cytia beds;” Localities 15 and 18.

**Subgenus DIMEROCRINITES (EUCRINUS)** Angelin, 1878

**Diagnosis:** Dimeroocrinites generally with twenty simple biserial arms; may have 3 to 4 arms per ray.

**Type species:** Eucrinus laevis Angelin, 1878.


**Discussion:** Angelin (1878) made a generic distinction between 10- and 20-armed dimerocrinitids of Gotland, naming the 20-armed form Eucrinus. Subsequent workers synonymized Eucrinus with Dimerocrinites even though the type species of Dimerocrinites is a 10-armed form; 20-armed dimerocrinitids (D. icosidactylus) were noted from the same locality as the type species (Wenlock Ls., England) and were included along with the 10-armed forms in the same genus, Dimerocrinites. In this study, Eucrinus will be assigned a subgeneric rank. D. (E.) laevis may be synonymous with D. (E.) interadialis; D. (E.) quinquangularis may be synonymous with D. (E.) speciosus. D. (E.) speciosus exhibits a variable-shaped (4-, 5-, or 6-sided) I Brl. D. (E.) interradialis, D. (E.) whittingli, and D. (E.) sp. may have pentagonal or heptagonal I Ax; D. (E.) lockportensis may have hexagonal or heptagonal I Ax. D. (E.) icosidactylus is the most atypical member of the subgenus having 3 or 4 (rarely 2) arms per ray and quadrangular I Brl; it
may variably have separated RR (Brower, 1973, p. 451). *Dimeroctenites* (*Eucrinus*) first appears in Late Llandoverian strata of North America; it is noted in Wenlockian strata of North America, England, and Gotland; its youngest occurrence is in Middle Devonian strata of New York.

**Dimeroctenites** (*Eucrinus*) sp.

Plate 1, Figs. 6, 7.

**Diagnosis:** Calyx obpyramidal; radiating pattern on plates; median ray ridge well-developed, bifurcating twice; posterior interray may have median anal ridge.

**Description:** Calyx obpyramidal, may be large; hexagonal IBrl, pentagonal or heptagonal 1Ax (see SUI 39820, 39815); hexagonal IBrl, secundibrachs incorporated into cup to third or fourth level. Interrays gently or not at all depressed; IBrl hexagonal bearing two plates in second range; interrays probably developed to fourth or fifth range. Radiating pattern connecting the centers of cup plates (evident internally on SUI 39958). Median ray ridges well-developed, bifurcating twice, leading to 4 arm facets per ray. Posterior interray may have median anal ridge running the length of the interray leading to the anus (SUI 39815); posterior interray may lack median anal ridge (SUI 39811). Tegment gently arched (SUI 39815).

**Discussion:** The poor preservation of the available material does not warrant specific assignment and it is left in open nomenclature. *D. (E.)* sp. is one of the largest crinoids in the “Cyclocrinites beds;” the largest dorsal cup (SUI 39958) is at least 43 mm high. Two other specimens measure (height \times width) 39 mm \times 37 mm and 24 mm \times 27 mm. The possibility exists that more than one species may be included under *D. (E.)* sp.: one form may have a lobate calyx with a median anal ridge developed, another form may lack a median anal ridge and have a weakly-lobate calyx.

**Material:** Twenty specimens are numbered SUI 39807 (2), 39808, 39809, 39810, 39811, 39812, 39813 (2), 39814 (2), 39815, 39819, 39820, 39958, 39971, 39972 (2), 39973 (2).

**Horizon and Locality:** “Cyclocrinites beds.” Localities 9, 17, 18, 19, 21, 22, 23, 27, 31, 35.

**Family DIMEROCTINITIDAE (?)**

**Genus ALLOZYGOCRINUS** n. gen.

**Type species:** *Allozygocrinus dubuquensis* n. sp.

**Diagnosis:** Modified zygodiplobathrid-type base, isolated quadrangular BB in contact only with iBB and RR, BB may be absent in at least one interradial position; iBB and RR large, elongate IBrl, possibly the 1Ax; first three IBrl are diminutive; posterior interray probably differentiated.

**Derivation of name:** The possible dimeroctinitid origins suggest a different sort of zygodiplobathrid development (allos, Gr., different).

**Allozygocrinus dubuquensis** n. sp.

Plate 2, Figs. 4, 5; Text-fig. 4.

**Description:** Dorsal cup elongate, rounded at base. Angular median ray ridge present. Infrabasals large, irregular in shape; quadrangular basals in contact with iBB below and RR above; suture with RR may be convex. Radials large, irregularly sized, roughly octagonal; first primibrach octagonal, elongate; second primibrach present. Interrays composed of numerous plates; first interbrachs small, pentagonal, flanked by two tiny triangular interbrachs laterally; third range interbrach in contact with all three IBrl proximally, flanked by two quadrangular plates laterally; two interbrachs in next range, probably hexagonal; additional interbrachs in following range. Arms, column, distal portion of cup, and ornamentation are unknown. SUI 42310 preserves a 29 mm portion of the cup, UC 63966 an 18 mm portion.

**Discussion:** The above description is based largely on the holotype, the most complete of the two known specimens (Text-fig. 4a). The second specimen (UC 63966) is more poorly preserved; it reveals 4 adjoining RR, 2 complete and 2 partial. It also reveals two completely isolated basals with convex distal margins; a third isolated basal may be present in the interradial position between the two preserved BB, although preservation is too poor to be certain. One elongate primibrach is preserved, and the median ray ridge is observed to branch at the distal end. This suggests that the rays branch from the IBrl, i.e. IBrl is probably the 1Ax on this specimen. The interrays of UC 63966 are poorly preserved, although the proximal portions seem to bear several diminutive plates.

An additional specimen (SUI 47222) from Locality 15 preserves part of the distal portion of a camerate dorsal cup and is tentatively assigned to *A. dubuquensis* (Text-fig. 4b). The elongate primibrachs, angular median ray ridges, and many-plated interrays of the specimen are reminiscent of features noted in *A. dubuquensis*, although the holotype and paratype preserve the proximal portions of the cup. SUI 47222 reveals branching of the median ray ridge from the elongate IBr2 (IBr2?); which contrasts with the condition noted in UC 63966. Additionally, the best preserved interray is wider and has a different plating arrangement than that noted on SUI 42310 and UC 63966; if SUI 47222 is correctly identified with *Allozygocrinus*, then the preserved interray probably occupies the posterior position. The other interray positions on the cup do not satisfactorily preserve the plating arrangement for comparison to *Allozygocrinus*, although the general interradial width is consistent.

The presence of a modified zygodiplobathrid-type of cup base and the complex interradial areas indicate that this taxon is a highly irregular camerate crinoid and may be an aberrant form. The occurrence of two specimens of nearly identical morphology, each in separate collections, increases the likelihood that the form represents a normally-developed and distinctive taxon. The elongate RR and IBrl are reminiscent of the ray structure noted in *Perichoecrinus*, and the form could conceivably be an unusual perichoecrinid.

Although the relationships of *Allozygocrinus* are certainly obscure, the form reveals features closely similar to an unusual dimeroctinitid *Dimeroctenites pentlandicus* noted in late Llandovery deposits of Scotland by Brower (1975). These features include the isolated quadrangular basal plate, multiple levels of IBrl, elongate RR, and elongate octagonal IBrl. *Allozygocrinus* differs in the greater development of the
iBB, by the possible loss of at least one basal, and in the greatly reduced proximal interbrachs. The similarities with the Scottish dimerocrinitid of the same age suggest the tentative dimerocrinitid relationship of Allozygocrinus. Brower (1975, p. 641) suggested that D. pentlandicus "is different enough from normal dimerocrinitids for a new genus to be proposed." With this in mind, and considering the even more divergent and unique platting arrangement of the Hopkinton taxon, a new genus seems warranted. The Hopkinton specimens, although certainly not ideally preserved, sufficiently illustrate the unique character of the genus. The diagnosis of Allozygocrinus could reasonably be modified to include forms like D. pentlandicus (primarily by making interray diagnosis less restrictive), although such an assignment is relegated to later taxonomic studies.

The possible loss of at least one basal in Allozygocrinus, a genus probably derived from a form like D. pentlandicus, raises some intriguing possibilities concerning the hypothetical origins of certain monocylic camerates. However, it seems that the lost element must have been a dimerocrinitid (or other) stock in the Silurian. Although speculative, the continued loss of basalas in a form like Allozygocrinus would produce a monocylic (pseudomonocylic) base. However, the dicyclic-monocylic schism within the crinoids will probably continue to be of fundamental phylogenetic significance in relating most dicyclic and monocylic forms into more or less "natural" groupings at the order level (Wam, 1975).

**Derivation of name:** The occurrence in Dubuque County suggests the name: Horiaon and Locality: "Cyrtia beds," Locality 15.

**Family LAMPTEROCRINIDAE** Bather, 1899

**Diagnosis:** IBB, BB, and RR large; RR generally in contact except on posterior side, although RR may be separated; calyx asymmetrical, extra plates in posterior interray create a bulge that extends onto tegmen; tegmen rigid, strongly arched; anus opens through tube (modified from Moore & Laudon, 1943; Ubaghs, 1978).

**Discussion:** The diagnosis of the Lampterocrinidae given above was modified to include forms (i.e., Siphonocrinus nobilis) with separated radial circlets. The Lampterocrinidae was apparently derived from the Dimerocrinitidae via two independent lineages. The bulging of the posterior interray and tegmen along with the development of an anal tube in both Group 2 and Group 3 dimerocrinitids gave rise to two known lampterocrinid genera, Lampterocrinus and Siphonocrinus, respectively. Lampterocrinus and Siphonocrinus, both highly successful forms on the North American Silurian carbonate platform, remained endemic to North America throughout their history (Witzke et al., 1979). The oldest known lampterocrinids are from the late Llandoveryan, Hopkinton Dolomite of Iowa where both genera appear simultaneously; Lampterocrinus was probably an offshoot of Siphonocrinus but probably arose independently from 10-armed dimerocrinitids. The youngest lampterocrinids are from Ludlovian rocks of Oklahoma and Tennessee.

**Genus SIPHONOCRINUS** S. A. Miller, 1888

**Type species:** Glyptocrinus nobilis Hall, 1861; OD

**Diagnosis:** Calyx very asymmetrical, depressed interradially and lobed at arm level; posterior side of calyx greatly inflated; tegmen high, long anal tube developed; subtegmental ambulacra in grooves on interior surface of plates; 20 arms, grouped; column circular.

**Discussion:** Strimple (1963) erected a new lampterocrinid genus, Ochlerocrinus, to include two species with adjoining RR formerly included in Siphonocrinus (S. armosus, S. pentagonus); Siphonocrinus was retained as a genus for those forms (S. nobilis) with separated RR and was transferred from the Lampterocrinidae to the Archeocrinidae. However, Siphonocrinus nobilis does not consistently have separated RR (Weller, 1900, p. 87); the RR are generally separated only in larger specimens of the species (Rowser, 1932, p. 83). The radial circle of S. nobilis varies between forms referable to Strimple's (1963) two genera, Ochlerocrinus and Siphonocrinus; and Ubaghs' (1978) two superfamilies, Dimerocrinitecta and Rhodocrinitecta; Ochlerocrinus is herein regarded as a junior synonym of Siphonocrinus. S. dignis (Strimple, 1963, p. 73) has separated RR and should probably be assigned to the Rhodocrinitecta.

Wachsmuth and Springer (1897, p. 213) erected a new species of Siphonocrinus, S. pentagonus, for forms "having but two arms to the ray" (ibid., p. 214). S. pentagonus is regarded herein as a junior synonym of S. nobilis; the type of S. pentagonus is an internal mold which superficially appears to have only 10 arm facets but is like S. nobilis in all other respects. However, many internal molds of S. nobilis from the Hopkinton Dolomite of Iowa and the Racine Dolomite of Wisconsin also appear to have only 10 arm facets even though external molds of the same species clearly have 20 arm facets. The paired arm facets of S. nobilis are spaced very closely together, and on internal molds these closely-spaced facets are often indistinguishable as pairs. S. armosus, a 20-armed form that also may appear to have only 10 arm facets on internal molds, is readily distinguished from S. nobilis by its long anal tube that lies flush along the tegmen surface and opens at the side of the calyx. Siphonocrinus probably originated from a 20-armed dimerocrinitid during the Late Llandoveryan; the oldest known representatives of the genus are from the Hopkinton Dolomite ("Cyrtia beds") of Iowa. Dimerocrinitecta (Eucrinus) sp. from the "Cyclopininctes beds" (Hopkinton Dol.) is a possible ancestor of Siphonocrinus.

**Siphonocrinus nobilis** (Hall, 1861)

**Plate I. Figs. 20-22**

**Diagnosis:** Anal tube directed upward; RR may be separated in large individuals; interrays developed beyond third or fourth range connected in uninterrupted succession with numerous plates on tegmen; arched tegmen about one-half total calyx height; external plate ornamentation with radiating stellate ridges; 4 arms per ray, grouped in closely-spaced pairs.

**Discussion:** Siphonocrinus nobilis is one of the dominant echinoderm elements noted in the "Cyrtia beds" at several Iowa localities. Several specimens of this species are the largest echinoderms noted from the entire Hopkinton Dolomite. Preserved RR circles on five specimens (SUI 39844) reveal the RR in lateral contact; on one specimen (SUI 39847) the RR are separated. Calyx size and shape, development of the anal tube, variation in the RR circle, and external plate ornamentation revealed in the Hopkinton Dolomite sample are identical with that noted in collections of S. nobilis from the younger Racine Dolomite (Wisc., Ill.), and the Hopkinton specimens are assigned without reservation to the species. Representative measurements of calyx size variation (height exclusive of anal tube × maximum width) from the Hopkinton sample are: 15 mm × 14 mm, 34 mm × 29 mm, 40 mm × 34 mm, 58 mm × 50 mm, 68 mm × 51 mm, 68 mm × 58 mm, 62 mm × 49 mm.

**Material:** One-hundred seventy-two specimens are numbered SUI 543, 31788 (9), 39844 (7), 39845 (70), 39846 (4), 39853 (12), 39854 (32), 39855, 39856 (2), 39857 (3), 39858 (4), 39859 (40), 39951, 39980 (7) and 39981 (8).

**Horizon and Locality:** "Cyrtia beds," Localities 1, 2, 3, 7, Bioherms; Localities 4, 43.

**Genus LAMPTEROCRINUS** Roemer, 1860
Type species; Lampterocrinus tennesseensis; M. Lampterocrinus sp. Plate 2, Figs. 1-3; Text-fig. 5

Diagnosis: Calyx elongate, decidedly pentagonal in cross-section; median ray ridges developed on internal molds; coarse stellate ribbing developed on plate exteriors; IBR2 quadrangular.

Description: Calyx elongate, pentagonal in cross-section, constructed at level of infrabasals, expanding upward to arm bases. Five basals, 4 equal, 1 slightly larger (see SUI 39954). Infrabasals hexagonal, large, similar in size to RR. Observed radials heptagonal, in contact all around except possibly on posterior side. First primibrachs hexagonal; second primibrachs quadrangular; third primibrachs bear arm facets. Median ray ridges evident on internal molds. First interbrachs hexagonal, similar in size to IBR1, bearing two interbrachs in next range. Third range interbrachs pass uninterruptedly from dorsal cup onto tegmen. Posterior interray not preserved on any specimens. Tegmen gently arched, gently bulged on posterior side (SUI 39953). Five arm bases. Exterior of plates decorated with coarse stellate ribbing (SUI 39955). Largest specimen 31 mm long; SUI 39953 measures 28 mm long x 17 mm wide.

Discussion: Although the available material from the Hopkinton Dolomite is poorly preserved and specific assignment is not attempted, the noted features are diagnostic of Lampterocrinus. Lampterocrinus sp. from the Hopkinton Dolomite exhibits a gently bulged posterior side of the tegmen although the condition represented is primitive compared to the extreme interray and tegmen bulging exhibited in L. inflatus (Racine Dolomite). The ornamentation, plate arrangement, and general calyx shape of L. sp. is most closely comparable with L. tennesseensis from the Ludovician Brownsport Formation. Lampterocrinus was probably derived from a 10-armed dimerocrinitid during the late Llandoverian (see discussion under Dimerocrinites (Dimerocrinidae) hopkinsonensis).

Material: Thirty-six specimens include the primary reference specimens SUI 39952, 39953 (2), 39954 (4), and 39955 and additional material SUI 39956 (7) and 39957 (21).

Horizon and Locality: "Cyrtia beds;" Locality 15.

Family GAZACRINIDAE S.A. Miller, 1892

Diagnosis (emended): Infrabasals confined to basal concavity; a single large interbrach generally present in each interray although one or two small interbrachs may follow in the next range (3 small plates may follow primanal). Tegmen may have central, vertically-grooved "pyramid" or a short subcentral anal tube. Arms 10, simple, biserial; column round in cross section.

Discussion: The familial diagnosis of the Gazacrinidae utilized by Ubags (1978) is so restrictive as to include only a single genus, Gazacrinus. A new genus discovered in the Hopkinton Dolomite that is closely related, if not ancestral, to Gazacrinus could not be placed within the Gazacrinidae without emending the existing familial diagnosis. This new genus (Pregarazacrinus), although derived from a dimerocrinitid stock (Moore & Laudon, 1943, p. 84), differs markedly in dorsal cup structure from most genera presently included in the Dimerocrinidae in having the interbrachs developed to only the second range (large IBR1, small IBR2) and in having a simplified brachial series. Pregarazacrinus is more easily grouped with Gazacrinus than with any other genus in the Dimerocrinatidae, and the diagnosis of the Gazacrinidae is emended to include both genera. The Gazacrinids represent a grade of dorsal cup evolution derived from a dimerocrinitid stock by the development of a basal concavity and by the elimination of the distal secundibrachs plus all interbrachs beyond the first or second ranges. Pregarazacrinus apparently lacks a specialized tegmen, although an anal tube is present; Gazacrinus possesses a specialized tegmen with few interambulacras and a central, vertically-grooved "pyramid" (possibly for the retractile reception of arms as in Eucalyptocrinites). Gazacrinus can easily be derived from Pregarazacrinus by the elimination of the second range interbrachs from the cup and by the development of the "pyramid." The Gazacrinidae was apparently derived from a dimerocrinitid stock sometime in the late Llandoveryian; it persisted into the Pridolian (Strimple, 1963, p. 88). The immediately ancestral dimerocrinitid stock is expected to display a slightly flattened dorsal cup, few fixed brachials, interrays developed to only the second or third range, ten arms, and a short anal tube; Dimerocrinites decadacrylus is a good example of such a grade of dimerocrinitid development (J. Brower, 1980, pers. comm.). The Gazacrinidae remained endemic to North America throughout the Silurian (Witzke et al., 1979).

Genus PREGAZACRINUS n. gen.

Type species: Pregarazacrinus hemisphericus n. sp.

Diagnosis: First interbrachs followed in next range by 2 small plates; primonial followed by 3 small plates. Tegmen lacks pyramid; anus subcentral, at end of short tube.

Discussion: Pregarazacrinus resembles Gazacrinus in many respects: the iBB are restricted to a basal concavity; the basals, radials, primibrachs, and secundibrachs are identical in general configuration; dorsal cup is subgloboso. Pregarazacrinus differs from Gazacrinus in lacking a central "pyramid" on the tegmen (it is not known if all species of Gazacrinus possess this feature) and in having second range interbrachs present. Gazacrinus major from the Racine Dolomite (Weller, 1900, p. 79) has a single second range interbrach per interray, a condition aligning it closely to Pregarazacrinus (also with second range IBR1). Rowser (1932, p. 85) first noted the similarity of the Iowa form to Gazacrinus.

Derivation of name: "Preceding Gazacrinus."

Pregarazacrinus hemisphericus n. sp.

Plate 1, Figs. 23, 24; Text-fig. 6

Description: Calyx small, subgloboso; basal concavity incorporates iBB and proximal portion of BB. Infrabasals 5, small, quadrangular.

Fig. 5. Plate diagram of Lampterocrinus sp., Hopkinton Dolomite, Iowa. Posterior side not shown; RR black.
Lateral basals pentagonal to hexagonal, similar in size to iBrl; posterior basal in contact distally with priranal. Radials large, in contact except on posterior side; RR hexagonal in C and D rays, heptagonal in remaining rays, twice as wide as high. First primibrach rectangular, twice as wide as high; primaxil larger than iBrl; single secundibrachs present per half-ray. Octagonal first interbrachs occupy about two-thirds of each interray, followed in second range by two small interbrachs in contact with tegmen. Primanals bear 3 small interbrachs in second range. Tegmen structure unknown; short anal tube developed in posterior interambulacral area. Plate exteriors unknown; 10 arms. Holotype measures (height x width) 6 mm x 6.5 mm.

Derivation of name: The specific name is retained from Rowser (1932, p. 86), a nomen nudum; hemispheric refers to the globular shape of the cup.

Holotype: SUI 31772 (Locality 2).

Material: Additionally SUI 31773 (5) and 42303 serve as paratypes.

Discussion: Moore's (1952) suborder Tanaocrininia should probably be given priority over Ubaghs' (1978) new suborder Compococrinina. Moore and Lauden (1943) first informally defined this suborder as the "Tanaocrinid stock" to include both the "periechocrinid section" (i.e. Periechocrinacea) and the "desmidocrinid section" (i.e. Carpocrinae and Hexacrinitae). And, therefore, it includes exactly the same taxa included in Ubaghs' Compocrinina. The diagnosis of the Tanaocrininia given by Moore (1952, p. 614) states that the basal circle "typically" has three plates, although Moore and Lauden (1943, p. 87) admitted that primitive members of this group may have four basals. Even though Tanaocrinus is apparently a junior synonym of Canistrocrinus, the Tanaocrininae and Tanaocrininia should remain valid higher taxonomic names, and the Compocrinina is herein regarded as a junior synonym of the Tanaocrininia. Ubaghs (1978) did not explain the reasons for rejecting Moore's (1952) suborder.

Superfamily PERIECHOCRINACEA Bronn, 1849
Family PERIECHOCRINIDAE Bronn, 1849
Genus PERIECHOCRINUS Morris, 1843

Discussion: The periechocrinids had apparently radiated from the tanaocrinid stock in North America by the latest Ordovician or earliest Silurian; Brower (1973, p. 332) reported a periechocrinid in the Edgewood Fm. of Missouri. The Hopkinton Dolomite specimens (late Llandoveryian) are the oldest known representatives of Periechocrinus; the genus was cosmopolitan during the remainder of the Silurian.

Periechocrinus sp. A
Plate 2, Fig. 6; Text-fig. 7A

Diagnosis: Cup globose; IBrrl equidimensional; primaxil pentagonal; second range iBrrl hexagonal to heptagonal.

Description: Globose cup; radials equidimensional, hexagonal; primibrachs equidimensional, hexagonal, slightly smaller than RR and iBrl; primaxil pentagonal, smaller than IBrl; first secundibrachs pentagonal to heptagonal; arm facets probably on third iBrrl; iBrrl present. First interbrach hexagonal, bearing two plates in next range, one hexagonal and one heptagonal; interrays probably developed to fifth range; median ray ridge runs the length of each ray; base of cup, posterior interray, and arms not preserved. A single cup measures 19 mm high and 19 mm wide.

Discussion: A single partial specimen of Periechocrinus from the "Cyclocrinites beds" is, at present, the oldest known representative of the genus. The contemporary Carpocrinus bodei resembles P. sp. A in general cup characteristics but differs primarily in the shape of the iBrl.

Material: SUI 45880.
Periechocrinus sp. B
Plate 2, Figs. 7,8; Text-fig. 7A,B

Diagnosis: Cup elongate; IBrl elongate; primaxil heptagonal; second range IBrl pentagonal to hexagonal.

Description: SUI 39804 and 39871, the primary reference specimens, reveal the following features: elongate cup; base hexagonal; radials elongate, hexagonal, smaller than first IBrl and RR; primaxil heptagonal, smaller than IBrl; first secundibrachs hexagonal; first interbrach hexagonal, bearing two plates in next range, one pentagonal and one hexagonal; interrays arranged in order 1:2:2:2:1; primanal heptagonal, not as high as the adjacent RR, bearing three plates in next range; median ray ridge running the length of each ray. Arms and column unknown.

Discussion: Although the observed features clearly place the 'Cyclocrinites beds' specimens within Periechocrinus, the features are not sufficient to place it within a described species. The internal molds of P. infelix and P. necis from the Racine Dolomite are the most similar to the Hopkinton specimens.

Material: SUI 39804, 31755 (6), 39871 (internal, external), 39872 (2).

Horizon and Locality: ‘Cyclocrinites beds’; Localities 1, 7, 42 (sec. 10).

Superfamily CARPOCRINACEA de Koninck & Le Hon, 1854
Family CARPOCRINIDAE de Koninck & Le Hon, 1854
Genus CARPOCRinus Muller, 1840

Type species: Actinocrinites simplex Phillips, 1839; Roemer, 1855, SD.

Discussion: The Carpoocrinidae and Periechocrinidae were both derived sometime in the latest Ordovician or early Silurian, and confusing similarities are evident in the early history of both families. The superfamilial distinction made between these two groups by Ubaghs (1978) is not directly applicable to many of the known Silurian forms. If the carpoocrinids and periechocrinids are to be included within the same superfamly, the Periechocrinacea has priority. The distinctions between Carpoocrinus and Periechocrinus, two genera assigned by Ubaghs (1978) to different superfamilies, are often confusing. Carpoocrinus differs from Periechocrinus in having two rather than four arms per ray and thicker plates with beveled edges (Slocum, 1907, p. 204). Ubaghs (1978), however, also placed some 10-armed forms in Periechocrinus. The primaxil is generally heptagonal in Periechocrinus and commonly pentagonal in Carpoocrinus; Periechocrinus also has a more elongate calyx with proportionately longer ray plates. Periechocrinus and some Carpoocrinus have hexagonal IBrl. Kirk (1946) erected the genus Stiptocrinus to include forms variously referred to Saccocrinus, Periechocrinus, Habrocrinus, and Aerocrinus but did not place the genus within a family. The description of Stiptocrinus given (Kirk, 1946, p. 33) agrees well with the diagnosis of Carpoocrinus (Ubaghs, 1978), and Stiptocrinus is considered a junior synonym of Carpoocrinus. Kirk only considered American forms and did not compare Stiptocrinus with the known European Carpoocrinus (= Habrocrinus, Pionocrinus). The oldest known Carpoocrinus are from mid late Llandovery strata in Iowa; the Carpoocrinidae may have been derived from a 'periechocrinid 'sometime in the Llandovery of North America (see discussion in Frest and Strimple, 1977, p. 134).

Carpocrinus bodei n. sp.
Plate 2, Figs. 9-12; Text-fig. 8

Horizon and Locality: ‘Cyclocrinites beds’; Localities 1, 7, 42 (sec. 10).
**Discussion:** Carpocrinus bodei reveals two primitive features aligning it with a tanaocrinid or periechocrinid ancestry: development of median ray ridges and unequal basals. The specimen shows a wide variation in cup shape. Interrays generally pentagonal, smaller than RR; primanal and the plates it supports should not be used in the superfamily diagnosis. Although the plating arrangement is completely different, it is similar in general shape to Krinocrinus, although the plating arrangement is completely different. The differentiation of the CD interray is not a consistent feature and is not included in the diagnosis for this reason.

**Material:** Eight specimens are numbered SUI 39805 (5), 39806, 39961 (2).

**Horizon and Locality:** "Cyria beds;" Locality 15.

**Suborder GLYPTOCRININA Moore, 1952**

**Superfamily PATELLIOCRINACEA Angelin, 1878**

**Diagnosis:** Glyptocrinitina with few fixed Brr in calyx; iBrl composed of a small number of plates, RR large relative to iBrr; arms uniserial, biserial, or compound Brr; column cylindrical.

**Remarks:** Ubaghs (1978) included in his diagnosis of the Patellocri­nacea, “first primibrachs quadrangular,” a feature inconsistent with several patellio­crinacean genera that have hexagonal iBrl including some Eopatelliocrinus (Brower, 1973, p. 332) and Macro­stylocrinus (ibid., p. 363) and all new patellio­crinacean genera described herein. Brower (1973, p. 363) found that in Macro­stylocrinus “rarely the primanal is followed by two, four, or five plates with or without an anal interray.” Other patellio­crinacean genera do show little or no differentiation of the CD interray in which the proximal interradials and the primanal are followed by from none to three plates (e.g., Patello­crinus, Allo­crinus, Lauro­crinus, Thomas­ocrinus). In Patello­crinus genera the CD interray is differentiated, generally by the inclusion of an extra plate immediately above the primanal (e.g., Eopatelliocrinus, Stele­docinus, Bolic­rinus). In Krinocrinus the primanal is followed by two plates, a feature identical to the lower iBrr of the lateral interrays, but the wider distal region of the CD interray is differentiated from the narrower distal region of the lateral interrays. Although the Patello­crinacea typically three plates following the primanal (Ubaghs, 1978), there are known patellio­crinaceans with no, one, two, five or six plates following the primanal. The primanal and the plates it supports should not be used in the superfamily diagnosis although the variability of this region may be of generic significance.

**Family PATELLIOCRINIDAE Angelin, 1878**

**Diagnosis:** Patello­crinacea with BB circlet usually with 3 plates, generally two large, one small (or BB fused); calyx conical to subglobose or subcylindrical; tegmen with numerous plates; uniserial, biserial, or compound Brr arms; arms 2 or 4 per ray.

**Remarks:** The diagnosis given above is essentially that of Brower (1973, p. 331), although calyx shapes follow Ubaghs (1978). Moore and Laudon (1943, p. 98) noted in their diagnosis of the Patello­crinidae that the “anal side commonly differentiated by extra plates.” Ubaghs (1978) took another view in his diagnosis noting that the “CD interray ordinarily little or not at all differentiated in calyx.” Although some patellio­crinid genera do show little or no differentiation of the CD interray, others display differentiation of the CD interray to varying degrees (Macro­stylocrinus, Eopatelliocrinus, Bolic­rinus, Krinocrinus). The differentiation of the CD interray is not a consistent feature in the family and is not included in the diagnosis for this reason. Bolic­rinus and some Macro­stylocrinus have a rigid tegmen; the presence of an incomp­tent tegmen should not be included in the diagnosis of the Patello­crinidae as Ubaghs (1978) has done.

**Genus BOLICRINUS n. gen.**

**Type species:** Bolic­rinus globosus n. sp.
Fig. 9. Plate diagrams of Bolicrinus, Lower Silurian, Iowa. A) B. globosus, B) B. deflatus, C) B. deflatus specimen (SUI 39788) with single third range iBrr. RR black; primanal with X.

**Diagnosis:** A genus of the Patelliocrinidae with hexagonal first primibrachs, pentagonal primaxilis; 2 fixed secondibrachs in each half-ray; flat to gently convex basal circle; radials largest plates in cup; first interbrach large, hexagonal, followed by two plates in second range; interrays developed to fourth range; CD interray differentiated, heptagonal primanal bearing 3 plates. Calyx globose to bowl shaped, contracting distally; tegmen flat; 10 arms.

**Discussion:** The well-developed interrays of Bolicrinus, a primitive feature in the Patelliocrinidae, align the genus most closely with some Macrostylocrinus and Eopatelliocrinus. Upper Ordovician Eopatelliocrinus and Macrostylocrinus from the Girardeau Limestone of Missouri (Brower, 1973) possess hexagonal primibrachs in some specimens, and interbrachs may be present to the fifth or sixth range in adult forms; this Upper Ordovician grade of patelliocrinid evolution is reminiscent of (and probably ancestral to) that noted in Bolicrinus. Bolicrinus differs from Eopatelliocrinus in its globular to bowl-shaped cup, competent tegmen, and slightly reduced interray development (although iBrr are proportionately larger). Forms here assigned to Bolicrinus could be lumped within a broadly defined Macrostylocrinus, although the distinctive bowl-shaped to globular cup shape, hexagonal primibrachs, and well-developed interrays readily distinguishes Bolicrinus from most species included in Macrostylocrinus. Macrostylocrinus is a broadly defined genus including a confusing array of patelliocrinid forms. Patelliocrinid forms with hexagonal primibrachs and globular cup shapes are included in the new genus Bolicrinus, partly in an effort to avoid burgeoning the genus Macrostylocrinus with additional forms and partly to reflect the independent Bolicrinus-Thomasocrinus evolutionary line. The reduction in interray width in Bolicrinus probably led directly to the subcylindrical form, Thomasocrinus. Bolicrinus globosus is one of the most common and distinctive crinoids in the "Cyclocrinites beds." The group of Iowa Silurian patelliocrinids with hexagonal primibrachs includes Bolicrinus, Thomasocrinus, Krinocrinus, and two species included for convenience in Macrostylocrinus; these forms represent a grade of patelliocrinid evolution that achieved its greatest degree of diversification and success during the Early Silurian.

**Derivation of name:** Bol (Greek), rounded mass.

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**Bolicrinus globosus n. sp.**

Plate 2, Figs. 15-23; Text-fig. 9A

**Diagnosis:** Dorsal cup globular; cup height greater than or equal to maximum cup width; basal circlet width/maximum cup width greater than 0.4.

**Description:** Dorsal cup globular, constricting towards oral surface, widest at the top level of the proximal interradials. Basal pentagon slightly convex internally; three basal, 2 large, 1 small; smallest B aligned with AE interray. Five hexagonal radials, the largest plates in cup, connected in an uninterrupted circlet. First primibrachs hexagonal, smaller than RR and proximal iRR. Primaxil pentagonal, smaller than second range of iRR. First fixed secondibrach hexagonal; second fixed secondibrach small, bears arm facets. Smallest ray plate is a single fixed intersecondibrach per ray. First interbrachs are second largest plates in cup; hexagonal iBrr bears 2 iBr on their distal margins, one pentagonal and the other heptagonal (heptagonal plate always adjacent to B or E rays). Primanal heptagonal, bears 3 iBrr on distal margin (2 lateral iBrr hexagonal, central iBrr pentagonal). Third level of iBrr with one pentagonal and one hexagonal plate in every lateral interray; in CD interray both plates are hexagonal. One very small fourth level iBrr in each interray at distal margin of cup. Lateral interrays arranged in order 1:2:2:1; posterior interray arranged in order 1:3:2:1. Tegmen flat; ambulacra branching outward into 10 arm facets. Anus laterally situated on side of CD interray; anus elevated on internal molds indicating that the anus opened directly through the tegmen. A single specimen (UC 63141) reveals an external plate ornamentation of ridges perpendicular to plate sutures. Structure of column or arms unknown. Observed size variation: height, 10-31 mm, maximum width, 9.5-30.5 mm. Shape variation: height/maximum width, 1.0-1.3.

**Derivation of name:** Globosus refers to globular shape.

**Holotype:** SUI 39692 (Loc. 28)

**Material:** One-hundred specimens include paratypes SUI 39767, 39768, 39769 (2), 39970 (5), 39774 (4), UC 63141 and additional specimens SUI 39771 (12), 39772 (21), 39775 (7), 39776 (2), 39773, 39777 (2), 39778 (2), 39779, 39780, 39781, 39782 (2), 39783 (17), 39784 (2), 39785 (2), 39786 (3), 39787 (11).
**Derivation**

**B. deflatus.**

**Description:** Thomasocrinus crinus, crinus

**Type species:** Thomasocrinus cylindrica

**Horizon and Locality:**

**Holotype:** Material:

**Discussion:** The lateral interrays of B. deflatus are arranged in order 1:2:2:1 or 1:2:1:1. External ornamentation consists of coarse to fine striae alligned perpendicular to the plate sutures (UC 63141). Tegmen flat. Size variation: height, 5-18 mm, width, 7-23 mm. Shape variation: height/width, 0.6-0.8.

**Derivation of name:** Deflatus., deflated bowl-shaped cup.

**Holotype:** SUI 39791 (Loc. 23).

**Material:** Additional material SUI 39788 (2), 39789, 39970, 39792 (5), 39793, 39959. UC 63141 (int., ext.).

**Horizon and Locality:** "Cyclocrinites beds;" Localities 11, 21, 23, 28.

**Genus THOMASOCRINUS n. gen.**

**Type species:** Thomasocrinus cylindrica n. sp.

**Diagnosis:** A genus of the Patelliocrinidae with hexagonal first primibrachs, pentagonal to heptagonal primaxils; 2 fixed secundibrachs in each half-ray; gently convex basal circlet; radials largest plates in cup; first interbrach pentagonal; interrays developed to fourth range, only one iBr in each range (1:1:1:1). No differentiation of CD interray. Dorsal cup subcylindrical; tegmen flat; 10 arms.

**Discussion:** Thomasocrinus is one of the few patelliocrinids to have achieved nearly perfect pentamorous symmetry. The rays of Thomasocrinus are very similar to those noted in Bolicrinus; the difference between the two genera lies primarily in the interrays. The linear arrangement of four interbrachs per interray in Thomasocrinus is markedly different from the more developed interrays of Bolicrinus. Bolicrinus is the most likely ancestor of Thomasocrinus; no descendents from this stock are known in any Wenlockian or younger deposits.

**Derivation of name:** Rowser (1932) proposed the name Thomasocrinus, then a nomen nudum, in honor of Prof. A.O. Thomas, University of Iowa, and the proposal is reiterated herein.

**Thomasocrinus cylindrica n. sp.**

**Plate 2, Figs. 30-33; Text-fig. 10**

**Description:** Dorsal cup subcylindrical; basal pentagon gently convex internally; 3 basals, 2 large, 1 small. Radials approximately equidimensional, hexagonal to gently heptagonal, largest plates in cup. First primibrach hexagonal, primaxil pentagonal to heptagonal, if hexagonal or heptagonal in contact with iBr3. First interbrach pentagonal, supporting one hexagonal to octagonal interbrach in second range (if octagonal, in contact with iBr1). A single third range iBr per interray, hexagonal; single fourth range iBr per interray. All five interrays arranged in order 1:1:1:1. No apparent differentiation of CD interray; cup achieves apparent pentamorous symmetry. Tegmen flat; 10 arm facets. External surface of plates probably smooth. Structure of column or arms unknown. Observed height variation, 8.5-23.2 mm.

**Height/width ratio, 1.5-1.6.**

**Discussion:** None of the specimens preserves the cup plates in its entirety, although a series of partial specimens outlines the general cup characteristics. The largest specimen (UC 64720) is the only one with octagonal iBr2 and pentagonal IAx; this specimen may represent another species of the genus, although these differences were more likely generated during ontogeny. The smaller specimens of T. cylindrica have heptagonal or hexagonal IAx that are in contact with one or both adjacent iBr2 and iBr3, whereas the IAx of UC 64720 does not contact the iBr3.

**Holotype:** SUI 31600 (partial internal and external).

**Material:** Thirteen paratypes numbered SUI 31601 (11), 39870, and UC 64720. Three poorly preserved and slightly larger specimens, SUI 31602, are tentatively included in this species.

**Horizon and Locality:** "Cyrtia beds;" Localities 1, 18, 42 (sec. 10).

**Genus KRINOCRINUS n. gen.**

**Type species:** Krinocrinus inflatus n. sp.

**Diagnosis:** A genus of the Patelliocrinidae with hexagonal first primibrachs, heptagonal primaxils; conical basal pentagon; hexagonal radials largest plates in cup. First interbrachs, including primanal, hexagonal supporting two hexagonal iBr in second range; interray well developed to fifth or sixth range; CD interray differentiated in its wider distal region. Dorsal cup conical, contracting distally; 10 arm facets.

**Discussion:** The CD interray of Krinocrinus is primarily differentiated in its distal region, a feature that would make it unique among the members of the Patelliocrinidae. The inclusion of Krinocrinus in the Patelliocrinidae is based on the large RR, a basal pentagon, and a conical cup. The noted occurrence of the primanal supporting two plates in some Macrostylocrinus (Brower, 1973, p. 363) lends further support to the familial assignment of Krinocrinus. Krinocrinus was apparently derived from a Macrostylocrinus-stock, but Krinocrinus-like forms are unknown in collections from younger Silurian strata. The development of a distally inflated CD interray is reminiscent of the highly successful but unrelated North American Silurian Lampterocrinidae.

**Derivation of name:** Krin (Greek, distinguish), the distally inflated CD interray distinguishes the genus.

**Krinocrinus inflatus n. sp.**

**Plate 3, Figs. 1-4; Text-fig. 11**

**Height/width ratio, 1.5-1.6.**

**Discussion:** None of the specimens preserves the cup plates in its entirety, although a series of partial specimens outlines the general cup characteristics. The largest specimen (UC 64720) is the only one with octagonal iBr2 and pentagonal IAx; this specimen may represent another species of the genus, although these differences were more likely generated during ontogeny. The smaller specimens of T. cylindrica have heptagonal or hexagonal IAx that are in contact with one or both adjacent iBr2 and iBr3, whereas the IAx of UC 64720 does not contact the iBr3.

**Holotype:** SUI 31600 (partial internal and external).

**Material:** Thirteen paratypes numbered SUI 31601 (11), 39870, and UC 64720. Three poorly preserved and slightly larger specimens, SUI 31602, are tentatively included in this species.

**Horizon and Locality:** "Cyrtia beds;" Localities 1, 18, 42 (sec. 10).
**Genus MACROSTYLOCIRINUS** Hall, 1852

*Type species:* *Macrostylocirinus* ornatus; M

**Discussion:** *Macrostylocirinus* (Late Ordovician-Early Devonian) exhibits a wide range of variation in calyx shape, degree of development of the interrays, and shape and size of the primibrachs in the included species. *Macrostylocirinus* presently includes a diverse group of patellocrinids; further work will probably necessitate splitting the genus into several taxa with more restricted diagnoses. The dorsal cup shape in *Macrostylocirinus* presently ranges between conical, subglobose, bowl-shaped, and subcylindrical. The radials are consistently large. The first primibrach varies between greatly compressed-rectangular forms and elongate-hexagonal forms; the primaxil varies between compressed pentagonal (approaching obliquely triangular) forms and elongate heptagonal forms in the various species. These variations in the primibrachs are already evident in two upper Ordovician forms, *M. cirrifer* (England) and *M. pristinus* (Missouri). The primalan is generally followed by 3 or 5 plates in the next range, although forms are known in which 2, 4, or 6 plates follow the primalan [Springer (1926, p. 181) illustrated a *M. laevis* in which 6 plates follow the primalan.] The CD interray is always differentiated in *Macrostylocirinus*. Interrays are developed to varying degrees in the different species: development to the second range in some species and to the fifth range and beyond in other species such as *M. fasciatus*, *M. cirrifer*, and *M. pristinus*. If the lateral interrays are not developed beyond the first range (i.e., only one large IBr per interray) or if the second range consists of 1 or 2 diminutive plates connected with the tegmen, such forms are referred herein to *Alloctenus* (emended). The Late Ordovician *M. cirrifer* to Early Silurian *M. silurocirrifer* lineage (Brower, 1975, p. 638) is probably an independent line of macrostycrinid evolution that was followed in western Europe. Nine of the patellocrinid species from the Hopkinton Dolomite are lumped in *Macrostylocirinus*; for the most part these forms are represented by poorly preserved specimens distinguished from each other largely by cup shape and ray structure.

*Macrostylocirinus* sp. A

Plate 3, Figs. 5-7; Text-figs. 12(1,13(1,2,3)

**Holotype:** SUI 39822 (partial external and internal mold; Loc. 11).

**Material:** Paratypes are numbered SUI 39823 (internal), 39781 (external), 39821 (internal), and 39824 (internal). Twenty-two additional specimens include SUI 39825 (int. & ext.), and internal molds SUI 39826 (9), 39827 (2), 39828, 39829 (5), 39830 (2), 39831(3).

**Horizon and Locality:** "Cyclocrinites beds;" Localities 9, 11, 16, 23, 28, 35.

**Fig. 11. Plate diagram of Krinocrinus inflatus (distal portion of interrays unclear). RR black; primalan with X.**

**Description:** Dorsal cup conical, contracting toward oral surface; basal pentagon internally conical, forming steep sides externally; number of BB brachs hexagonal. Distal region of rays indeterminate. Hexagonal first developed, plates developed to at least the fifth, probably the sixth circlet. First primibrachs hexagonal, second largest plates interbrachs support two hexagonal IBr in second range. Interrays well developed. Primanal supports only two plates; CD interray differentiated in distal region being almost twice as wide as in the lateral interrays. Tegmen flat; 10 arm facets. Anus laterally situated above CD interray. External surface of plates smooth. Structure of column or arms unknown. Size variation: height, 10-40 mm, maximum width, 8-30 mm. Shape variation: height/maximum width, 1.2-1.4.

**Derivation of name:** Inflatus; characteristic feature is distally inflated CD interray.

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**Diagnosis:** Dorsal cup rounded at base, gently flaring above; coarse striae transect plate sutures; IBrl quadrangular; 3 fixed IIBr per half-ray.

**Description:** Dorsal cup rounded at base, gently flaring above to lobate; subcircular in cross-section proximally, pentangular toward arm bases. RR large, hexagonal; IBrl quadrangular; IBr2 pentagonal; 3 secundibrachs per half-ray. Proximal interbrachs bear 1 or 2 plates in next range. Posterior interray unknown. Coarse striae aligned perpendicular to plate sutures externally.

**Discussion:** This group of "Cyrtia bed" patellioicrinids is difficult to interpret due to poor preservation. Two different species may be lumped here under *M.* sp. A, one with coarse external striae, the other with a more lobate cup and possibly smooth plates. More material is necessary to properly diagnose the species. Any "Cyrtia bed" patellioicrinid with a rounded base, large RR, and prominent IIBr is here informally grouped in *M.* sp. A.

**Material:** Nineteen specimens available; primary reference specimens SUI 39832 (displays external) and SUI 39833 (2); additional specimens SUI 39834 (15) and 39867.

**Horizon and Locality:** "Cyrtia beds;" Localities 7, 15.

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**Macroystlocrinus** sp. C
Plate 3, Figs. 8, 9; Text-figs. 12(4), 13(6)

**Diagnosis:** Dorsal cup bowl-shaped, excavated at base; basals small; IBrl quadrangular.

**Description:** Dorsal cup bowl-shaped, excavated at base. Basal pentagon small, in depression on internal molds, 2 BB equal, 1 unequal. Radials visible primarily in basal view, hexagonal. IBrl rectangular, IBr2, pentagonal. First interbrachs large, probably decagonal; second range interbrachs present. Surface of plates probably smooth. Cup height, 9 mm; width, 16 mm.

**Discussion:** A single specimen from the "Cyclocrinites beds" exhibits a plate arrangement consistent with a simplified patellioicrinid form. It differs from other species of the genus in having the base excavated and in general cup shape. This form is tentatively referred to *Macroystlocrinus*, although it may represent an undescribed genus. By further reduction of the interrays, *M.* sp. C may be ancestral to *Allocrinus*.

**Material:** SUI 39985 (internal, external).

**Horizon and Locality:** "Cyclocrinites beds;" Locality 11.

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**Macroystlocrinus** sp. D
Plate 3, Figs. 12-15; Text-figs. 12(3), 13(5)

**Diagnosis:** Dorsal cup subconical; external ornament of coarse radiating ridges; IBrl hexagonal; tegmen rigid.

**Description:** Dorsal cup subconical, gently lobed at distal margins. 3 BB, 1 small, 2 large. Radials large, hexagonal to heptagonal. First primibrach hexagonal; primaxil pentagonal, secundibrachs incorporated in cup. Proximal interbrachs hexagonal, bearing 2 plates in next range; lateral interrays arranged 1:2:2:3:?, distal portion incorporated into tegmen. Posterior interray differentiated, primanal bearing 3 plates. Tegmen rigid, flat, preserved on all noted specimens; ambulacra lead to 10 arm facets; anus subcentral. External ornament of coarse radiating ridges. SUI 42280 (calyx) measures 16 mm high × 15 mm wide.

**Material:** 6 specimens are numbered SUI 39816 (external), 39817, 39818 (2), 42279, 42280.

**Horizon and Locality:** "Cyclocrinites beds;" Localities 16, 23, 27, 28.
**Macrostylocrinus sp. E**

**Diagnosis:** Dorsal cup subconical; external of plates nodose; IBrl hexagonal.

**Description:** Dorsal cup subconical, lobed at distal margin. Radials large, hexagonal to heptagonal; IBrl hexagonal; IBrl2 present; single intersecundibrach present per ray. Proximal interbrachs hexagonal; lateral interrays arranged 1:2:2:2. Posterior interray unknown. External of plates nodose. SUI 42282 (dorsal cup) measures 14 mm high x 11 mm wide.

**Discussion:** Internal molds of M. sp. E are similar to M. sp. D except that M. sp. E has a more steeply conical cup, more pronounced lobes, and apparently lacks a rigid tegmen. Externally the two species differ dramatically.

**Material:** Two specimens are numbered SUI 42281 (internal, external) and 42282.

**Horizon and Locality:** "Cyclocrinites beds;" Localities 11, 18.

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**Macrostylocrinus compressus n. sp.**

**Diagnosis:** Dorsal cup conical at base, subcylindrical above; pentagonal in cross-section at base, subcircular above; broad median ray ridge developed internally from base of cup to top of RR; IBrl distally compressed, subpentagonal.

**Description:** Dorsal cup obconical; 5 broad ridges present internally beneath level of primibrachs; radials very large, occupying almost one-half of cup height; distal margin of RR concave; first primibrachs distally compressed, subpentagonal, three times wider than high; primaxils about same size as IBrl, pentagonal. First interbrachs hepta­dramatically.

**Material:** Two specimens with group number SUI 39835 (Loc. 15).

**Holotype:** SUI 39835 (Loc. 15).

**Material:** Six paratypes with group number SUI 39836 and additional specimens SUI 39837 (16), 31770 (7), 39838, 39866.

**Horizon and Locality:** "Cyrtia beds;" Localities 1, 7, 15. Adjacent to bioherms; Locality 33.

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**Macrostylocrinus vermiculatus n. sp.**

**Diagnosis:** Rays form distinct lobes, interrays depressed (concave); dorsal cup expands broadly to base of arms; base conical; surface of plates with numerous delicate nodes; first primibrachs quadrangular.

**Horizon and Locality:** "Cyclocrinites beds;" Locality 16 (SUI 39843, Locality 11).
Description: Calyx higher than wide, conical at base, subcylindrical at level of radials, rays rapidly expanding to base of arms. Interrays depressed, rays forming distinct lobes. Radials large, almost one-half height of cup; lateral edges of RR parallel; first primibrach much smaller than RR, approximately square; primaxil pentagonal, roughly same size as IBrl. First interbrach probably octagonal, supporting two plates in next range; CD interray over 50% wider than lateral interrays. Surface of plates covered by numerous delicate nodes; rows of nodes between adjacent plates not interconnective. Tegmen, column, arms unknown. Holotype measures 15 mm high, 14 mm wide at arm bases, 7 mm wide at level of RR.

Discussion: Macrostylocrinus vermiculatus most closely resembles M. striatus, but differs in being relatively narrower at the level of the RR and by its delicate nodes on the plate surface. Macrostylocrinus striatus is ornamented by radiating striations.

Derivation of name: Vermiculatus refers to the ornamented surface of the plates (Rowser, 1932).

Material: Additionally 3 specimens are numbered SUI 31742.

Horizon and Locality: "Cyrtia beds;" Locality 1.

Macrostylocrinus cf. M. striatus Hall, 1863
Plate 3, Fig. 25; Text-figs. 12(9),13(10)

Discussion: Three poorly preserved internal molds from the "Cyrtia beds" at Locality 7, are tentatively assigned to M. striatus based on general calyx shape and the presence of three levels of interbrachial plates. The specimens differ from M. vermiculatus in being less lobate and in the shape of the IBrl.

Material: SUI 39868 (3).

Genus ALLOCRINUS Wachsmuth & Springer, 1890

Type species: Allocrinus typus; OD.

Diagnosis: Calyx low bowl-shaped, first interbrach large, may or may not be followed in next range by 1 or two small plates connected with tegmen; 1 or 2 small primibrachs and 1 or 2 small fixed secundibrachs per ray. Arms 10, simple. Columnals long with narrow pentangular axial canal.

Discussion: Described species of Allocrinus include a greater range of variation than Ubags' (1978) diagnosis suggests. Globular-cupped forms could be removed to a new genus with the basally excavated forms kept in Allocrinus, although the genus is herein treated in a broadly defined sense. Characteristically, most species of Allocrinus show little or no differentiation of the CD interray; however, A. globulus has a well differentiated CD interray (Strimple, 1963, p. 108). Allocrinus was probably derived directly from Macrostylocrinus by a reduction in interray height and distal compression of the fixed primibrachs and secundibrachs as the cup became more globose. These trends are evident in species such as Macrostylocrinus pustulosus. Allocrinus irroratus and A. divergens are atypical of the genus in displaying branching from the first primibrach (Strimple, 1963, p. 107); the extreme reduction in the height of the fixed brachials apparently resulted in the loss of the second primibrach in these species. Species with only one primibrach per ray are assigned herein to Allocrinus and the generic diagnosis revised accordingly; alternatively, forms with one IBrl per ray could also be referred to a new genus. Allocrinus irroratus, a species that represents an extreme in patellocrinid dorsal cup simplification, has three bases of equal size, a condition atypical of the family in general. "Macrostylocrinus" subglobosus has a subglobose cup, compressed primibrachs, and very large first interbrachs filling the interray spaces (Weller, 1900, p. 96); these features align the species with Allocrinus (A. subglobosus n. comb.). The Allocrinus from the Hopkinton Dolomite are the oldest known forms of the genus. Allocrinus probably diverged from a Macrostylocrinus stock sometime in the Llandovery.

Allocrinus cf. A. subglobosus (Weller, 1900)
Plate 2, Figs. 27-29

Diagnosis: Dorsal cup small, subglobose; basal pentagon gently convex; distal margin of radials concave; first primibrach subulate; first interbrach large, filling interrays; external of plates with delicate nodes.

Description: Dorsal cup small, subglobose, length and width about equal; three basal unequal forming gently convex pentagon; radials large, distal margin of radials concave; first primibrach small, twice as wide as high, subulate; primaxil pentagonal, about same size as IBrl. First interbrach large, practically filling the whole interray space; second range interbrachs either absent or very small; CD interray indeterminate in available Hopkinton specimens. External of plates marked by delicate nodes.

Discussion: The lack of distinct second range interbrachs, large first interbrachs, and a subglobose cup align the Hopkinton Dolomite specimens most closely with Allocrinus subglobosus (Macrostylocrinus subglobosus Weller, 1900, p. 96) from the Racine Dolomite of Illinois. Allocrinus subglobosus differs from the Hopkinton specimens in having a broadly arched tegmen, radials lacking distal concave margin, and first primibrachs perfectly quadrangular.

Material: Seventeen specimens are available numbered SUI 39839 (6), 31771 (10), and 39865.

Horizon and Locality: "Cyrtia beds;" Localities 2, 7, 15.

Allocrinus ornatus n. sp.
Plate 3, Figs. 26-29

Diagnosis: Dorsal cup subpentagonal in cross section; base of cup marked by broad, shallow basally excavated region; strongly convex radially ornamented RR.

Description: Dorsal cup subpentagonal in cross section; base of cup marked by broad, shallow basally excavated region; cup wider than high; 3 unequal BB; radial plates large, strongly convex, marked by radiating ornamentation. Primibrachs greatly compressed, over twice as wide as high; IBrl quadrangular with proximal margin commonly convex; IBrl2 pentagonal, nearly triangular. Two fixed secundibrachs per half-ray; interrays with single elongate interbrach. Observed cup width: 5-15 mm. Column, arms, and tegmen unknown.

Derivation of name: Ornatus refers to radiating ornamentation.

Holotype: SUI 39890 (Loc. 18).

Material: Ten paratypes are numbered SUI 39840, 39841 (9).

Horizon and Locality: "Cyrtia beds;" Localities 15, 18, 34.

Family MARSUPIOCRINIDAE Bronn, 1855

Genus MARSUPIOCRINUS Morris, 1843

Type species: Marsupiocrinites coelatus Phillips, 1839; M

Subgenus MARSUPIOCRINUS (AMARSUPIOCRINUS) Frest, 1975

Type species: Marsupiocrinus (Amarsupiocrinus) striatissimus Springer, 1926; OD

Discussion: North American species of Marsupiocrinus are distinguished largely on the basis of calyx shape, tegmenal curvature, size and shape of the basal pentagon, and plate ornamentation. The presence of a basil rim and two arms per ray distinguish Marsupiocrinus (Amarsupiocrinus) from Marsupiocrinus (Marsupiocrinus) with four arms.
Diagnosis: A species of Amarsupiocrinus with a plano-convex calyx; gently convex to gently concave basal pentagon about one-half the width of the dorsal cup; striato-corrugate plate ornamentation; anus laterally located; linear series of iambb flanked by two large iambb. Description: The calyx is plano-convex (i.e., tegmen flat or gently convex), although one specimen (SUI 39922) tentatively included in the species is biconvex (i.e., tegmen and dorsal cup of equal size and similar shape). The basal pentagon, always about one-half as wide as the dorsal cup, can be gently concave (most extreme in SUI 39919A), flat (e.g., the holotype), or gently convex (e.g., SUI 39911). A raised rim surrounds the column facet externally. The radials suture with the basals forming about a 140° angle. The radials of M. primaevus are among the least convex known for the genus and have a width/height ratio of 1.6 to 1.8. The tegmen, characteristically flat or gently convex, has prominent ambulacra bifurcating at about one-half their length. Ambulacra branch several times at lateral margin of tegmen, leading to two arm facets per ray. Numerous compressed interambulacrals (interbrachs) arranged in linear series, flanked by two large interambulacrals adjacent to ambulacra; iambb flat, delicately pustulose externally. Anus situated near lateral margin of tegmen (SUI 39923, 39920); posterior interambulacrals unknown. The lumen, if preserved, is pentalobate. The external plate ornamentation is to varying degrees striato-corrugate (see SUI 31723, 39923, 39924). The corrugated striations are aligned normal to the sutures they transect. Specimens vary in size; dorsal cups from the "Cyclocrinites beds" are between 7 and 31 mm wide, those from the "Cyrtia beds" are between 7 and 34 mm wide.

Discussion: Marsupiocrinus primaevus most closely resembles M. striatus and M. verneuili from much younger (Ludlovian) deposits in Tennessee but differs from both by its laterally-placed anus and the plating of the tegmen. The basal pentagon of M. primaevus is not broadly excavate nor is it bounded by a conspicuous triangular rim as in M. verneuili (Springer, 1926, p. 59). Less prominent interambulacral plates, less convex radials, and a basal pentagon that is commonly flat or convex contrasts M. primaevus with M. striatus.

Derivation of name: Primaevus, the most ancient representative of the Marsupiocrinidae.

Holotype: SUI 39923 (Loc. 15).

Material: Eleven specimens from the "Cyclocrinites beds" are numbered SUI 39906 (4), 39907, 39908, 39909, 39911 (2), 39912 (2); three specimens from beds adjacent to bioherms are numbered 39913, 39914 (2); 108 specimens from the "Cyrtia beds" include paratype SUI 39920 (5) and 39924 (4) and additional material SUI 31719, 31721, 31722 (2), 31723, 31724 (2), 31725, 31727 (3), 31728, 31729, 31730, 31732 (2), 31769, 39910, 39915 (2), 39916, 39917, 39918 (19), 39919 (40), 39921 (5), 39922 (2), 39925 (10).

Horizon and Locality: "Cyclocrinites beds" specimens from Localities 11, 16, 23, 24, 28, 33, 35, 36, 40 (sec. 33); "Cyrtia beds" and bioherm associated specimens from Localities 1, 2, 4 (SW sec. 9; sec. 10; c. sec. 25; SE sec. 35), 6, 15, 18, 22, 30, 34, 41 (sec. 19; SW sec. 36).

Fig. 14. Plate diagrams of two new species of Macrostylocrinus. A) M. compressus. B) M. vermiculatus (distal portion of posterior interrays unclear). RR black; primanal with X.

Fig. 15. Tegmen plating arrangement of Marsupiocrinus primaevus. Laterally situated anus colored black. Plating unclear in posterior interambulacral area.
Superfamily EUCALYPTOCRINITACEA Roemer, 1855

Family EUCALYPTOCRINITIDAE Roemer, 1855

Discussion: The diagnosis of the Eucalyptocrinitidae utilized in this study is from Ubaghs (1978) with some modification: fixed tertibrachs one or two in each quarter-ray, basal concavity may or may not be present. The dorsal cup is commonly wider than high in the superfamily (Ubaghs, 1978), although in Archaeocalyptocrinus and some Eucalyptocrinites (e.g., E. proboscidialis) the reverse is true. Moore and Landon (1943, p. 99) believed that the Eucalyptocrinitidae was derived from the Clonocrinidae, although the first occurrences of Archaeocalyptocrinus and Eucalyptocrinites predate the earliest known occurrence of the Clonocrinidae. The presence of a single interbrach in the second range of Clonocrinus, the oldest known representative of the Clonocrinidae, contrasts markedly with the two second range interbrachs of the Eucalyptocrinitidae and strongly precludes the origin of the Eucalyptocrinitidae directly from a form like Clonocrinus. Also, the basal invagination of Clonocrinus is an advanced feature compared to the most primitive conical base of Archaeocalyptocrinus. Both the Clonocrinidae and the Eucalyptocrinitidae were probably derived independently from a similar Patelliocrinid stock. Leurolocrinus is a good example of a patelliocrinid very close in form to the stock that gave rise to the Clonocrinidae and the Eucalyptocrinitidae; some Leurolocrinus even possess four BB (Springer, 1926, p. 186, fig. 13a).

Four genera are included in the Eucalyptocrinitidae: Eucalyptocrinites, Calliocrinus, Archaeocalyptocrinus, and Chicagocrinus. The first three of these genera are distinguished largely on the following features: size of IIIbr compared to IBr2, presence of a basal concavity, size of BB, extent of tegmen arm partitioning, development of the anal tube and its ornamentation, presence of spinose processes, and general calyx shape. Chicagocrinus, although regarded as a synonym of Calliocrinus by Ubaghs (1978), is considered herein as a distinctive member of the family typified by a greatly modified primibrach series (the complete loss of the quadrangular IBr1 along with reduction of IBr2 to a small triangular plate). Specimens from the Hopkinton Dolomite extend the range of Eucalyptocrinites and Calliocrinus down into the latest Llandoveryian, and the discovery of a new eucalyptocrinitid genus, Archaeocalyptocrinus, extends the range of the family down to at least mid late Llandoveryian. The Eucalyptocrinitidae probably diverged in North America from the Patelliocrinidae sometime during the Llandoveryian. By the Wenlockian Eucalyptocrinites and Calliocrinus had become nearly cosmopolitan in their distribution. Text-figure 16 summarizes the interpreted evolutionary changes noted in the family.

Genus ARCHAEOCALYPTOCRINUS n. gen.

Type species: Archaeocalyptocrinus nodosus n. sp.

Included species: A. nodosus n. sp., A. iowensis n. sp., A. obconicus (Hall), A. slocumii (Foerste).

Diagnosis: A genus of the Eucalyptocrinitidae with dorsal cup higher than wide; basalts extending up sides of cup, visible in lateral view; basal concavity absent or weakly developed; primaxil pentagonal; adjacent first secundibrachs share common suture; 1 or 2 fixed tertibrachs per quarter-ray; tegmen divided by 10 small vertical partitions; anus elevated into central vertical tube.

Discussion: Archaeocalyptocrinus differs from other members of the family in possessing primitive features such as an elongate calyx, large basalts, and weakly developed tegmen partitions (at least in A. nodosus). Archaeocalyptocrinus differs from Eucalyptocrinites primarily in cup shape, in having the basalts extending up the sides of the cup (instead of resting in an inverted basal funnel), and in having the first two secundibrachs in each ray sharing a common suture (i.e., primaxil pentagonal, does not contact intersecundibrach). Rarely, some species of Eucalyptocrinites (e.g., E. crassus) can have adjacent IBr1 in contact, although this condition is atypical; generally the primaxil contacts the intersecundibrach (Macurda, 1968, p. 102). The only species of Eucalyptocrinites that consistently has adjacent IBr1 in lateral contact is E. proboscidialis (Foerste, 1920, p. 72). Calliocrinus differs in having a broader basal concavity than Eucalyptocrinites with

Fig. 16. Phylogeny of the Eucalyptocrinitidae. Top figure illustrates changes in dorsal cup and tegmen configuration. Bottom figure illustrates the cross-section of the base of the dorsal cup; the development of an invaginated base is characteristic of Eucalyptocrinites, Calliocrinus, and Chicagocrinus. A) Ancestral Patelliocrinid (illustrated form is hypothetical), B) Clonocrinus (not a eucalyptocrinitid), C) Archaeocalyptocrinus nodusus, D) Wenlockian Archaeocalyptocrinus (A. slocumii shown), E) primitive Eucalyptocrinites with long anal tube and adjacent IBr1 in contact (E. proboscidialis), F) advanced Eucalyptocrinites with invaginated base and loss of anal tube above level of tegmen partitions (e.g., E. milliganae), G) spineless Calliocrinus (e.g., C. longispinus, C. murchisonianus), H) unspined Calliocrinus (e.g., C. costatus), I) Chicagocrinus. All RR are black.
very small basals restricted to the area of the column facet; some species of Calliocrinus have the first secundibrachs in lateral contact. Archaeocalyptocrinus, the oldest known member of the Eucalyptocrinidae, was apparently derived from a patellocrinid stock with an elongate calyx and a rigid tegmen. Subsequent reduction in calyx height, further specialization of the tegmen partitions, and invagination of the BB in Archaeocalyptocrinus would produce forms like Eucalyptocrinites and Calliocrinus.

Two species, formerly included in Eucalyptocrinites, are here transferred to Archaeocalyptocrinus: A. obconicus (Hall) and A. slocumi (Foerste). Archaeocalyptocrinus obconicus, known only from internal molds recovered in the Racine Dolomite of Wisconsin and Illinois (probably Wenlockian), has a dorsal cup much higher than wide, basals comb.) is the most steeply conical member of the genus Archaeocalyptocrinus, (1907) assigned to "Eucalyptocrinites" obconicus a specimen from the Chicago Drainage Canal; this specimen served subsequently as the type for a new species, "E." slocumii Foerste (1920, p. 72). Archaeocalyptocrinus slocumi (n. comb.) is the most steeply conical member of the genus, with extremely elongate basals extending up the sides of the cup to more than one-fifth the total cup height. The tegmen of A. obconicus and A. slocumi is unknown; the presence of small tegmen partitions given in the generic diagnosis is therefore tentative.

Archaeocalyptocrinus nodosus n. sp.

Plate 4, Figs. 4-7; Text-fig. 17

Diagnosis: Dorsal cup obconical, higher than wide; first interbrachs similar in size to radials; 2 fixed tertibrachs per quarter-ray; internal molds of cup strongly lobate, rigid tegmen elevated, divided by 10 small partitions; each cup plate with single large protruberant node. Description: Dorsal cup obconical, higher than wide; basal concavity developed externally, not evident internally; four basals unequal. Radials hexagonal, approximately equidimensional, in contact all around. First primibrachs quadrangular, smaller than RR; primaxil pentagonal, similar in size to IBrl. Adjacent first secundibrachs in lateral contact; second secundibranch pentagonal. Two fixed tertibrachs present per quarter-ray (see SUI 39860, 39905). Single intersecundibrach per ray above level of IBrl, smaller than IBrl. First interbrach decagonal, large, similar in size to RR, supporting one elongate interbrachs in second range. No differentiation of CD interray. Rigid tegmen elevated, externally bearing 10 small vertical partitions (SUI 39849); anal tube centrally located. Twenty arm facets project on lobes on internal molds. Externally, each plate of dorsal cup bears a single protruberant node (SUI 39850, 39860, 39905). Column and arms unknown. Size variation: calyx height (including tegmen), 6-15 mm (partial specimen to 19 mm); width, 4.5-18 mm. Discussion: Internal molds of A. nodosus bear a superficial resemblance to Siphonocrinus; 20 arm facets on lobes, elevated rigid tegmen, development of an anal tube. However, Siphonocrinus is a dicyclic many-plated form with pronounced asymmetry as opposed to Archaeocalyptocrinus, a monocyclic form exhibiting nearly perfect similarity in calyx shape and external plate ornamentation. Derivation of name: Nodosus, protruberant nodes on cup plates. Holotype: SUI 39848 (Loc. 28). Material: Four paratypes are designated SUI 39849 (internal, external), 39850 (internal, external), 39860 (internal, external), and 39905 (external). Nine additional specimens are numbered SUI 39851 (2), 39852 (2), 39847 (4), 39960. Horizon and Locality: "Cyclocrinites beds;" Localities 11, 17, 21, 23, 28.

Archaeocalyptocrinus iowensis n. sp.

Plate 4, Figs. 8-11; Text-fig. 17

Diagnosis: Dorsal cup elongate, gently expanding upward, higher than wide; first interbrachs larger than radials; single (?) fixed tertibrach per quarter-ray; cup not strongly lobate; surface of plates probably smooth. Description: Dorsal cup elongate, contracted at level of radials, gently expanding upward, higher than wide; external basal concavity unknown; on internal molds, base gently conical. Radials hexagonal, slightly wider than high, internal molds of radials concave. Rays in A. iowensis except a single (?) fixed tertibrach per quarter-ray (see SUI 39862). First interbrach decagonal, larger than radials. Tegmen not preserved on any specimens. Arm facets approximately flush with cup on internal molds; cup is not strongly lobate. Exterior of plates apparently unornamented (lacking large nodes as in A. nodosus). Observed dorsal cup dimensions (height x width): 9 mm x 7 mm; 11.5 x 10 mm (holotype); 13 mm x 10.5 mm; 20 mm x 14 mm. Derivation of name: Iowensis, all specimens are from Iowa. Holotype: SUI 39864 (Loc. 35). Material: Two paratypes are numbered SUI 39861, 39862; 4 additional specimens are numbered 39863 (2), 39869 (2). Horizon and Locality: "Cyclocrinites beds;" Localities 11, 16, 23, 32, 35.

Genus EUCALYPTOCRINITES Goldfuss, 1831

Type species: Eucalyptocrinites rosaceus; M

Diagnosis: A genus of the Eucalyptocrinidae with one or two primibrachs per ray; 4 small basals not visible in lateral view; base of dorsal cup generally invaginated (may have flat base); secundibrachs similar in size and shape to paired distal interbrachs; 10 riblike vertical partition plates on elongate tegmen forming alcoves for complete enclosure of the 20 arms (partition plates aligned with secundibrachs and paired distal interbrachs); central anal tube developed entire length of vertical tegmen partitions, in some species elongate plated anal tube developed well beyond distal margin of tegmen partitions. Discussion: The great profusion of species included in Eucalyptocrinites (over 50 species described in the literature and 13 additional species in Rowser’s unpublished 1932 dissertation) has not been adequately re-examined. Macurda (1968) and Kesling et al. (1973) measured plate proportions in collections of Eucalyptocrinites crassus from the Waldron Shale in order to define the observed ontogenetic changes. Macurda (1968) also included information on several other
species, particularly *E. tuberculatus*. A somewhat confusing array of variation was discovered; dorsal cup shape, individual plate shape, degree of basal invagination, and plate junctions all were found to be highly variable within collections of *E. crassus*, particularly those from Tennessee. Kesling et al. (1973, p. 46) noted a wide range of variation in dorsal cup shape in collections from Tennessee:

Adults vary more in shape than young crinoids. All small cups are conical. Some large cups are also conical, only slightly modified from the small ones, but more are markedly flattened. And among the cups that are flattened, there is a variety of profiles.

Variation in individual plates is significant, not only in general proportions, but also in shape (e.g., most IBr2 hexagonal, some pentagonal). Some specimens are missing the quadrangular IBr1 in one or more rays. The degree of basal invagination varies (p. 49) and plate junctions are not consistent within collections of *E. crassus*; “some plates change their junctions during ontogeny” (p. 11).

These comparisons of Waldron Shale collections from Indiana and Tennessee reveals a broad range of variation in calyx shape, plate proportions, and basal invagination that includes forms previously described under five different specific names; *E. crassus* was demonstrated by Macurda (1968) to be the senior synonym of *E. constriictus*, *E. ellipticus*, *E. ovalis*, and *E. subglobosus*. *E. tuberculatus*, also from the Waldron Shale, based on similarities in plate ornamentation was believed to be the senior synonym of *E. elrodi* although no intermediate forms actually link the high-cupped *E. tuberculatus* forms with the broad-cupped *E. elrodi* forms. The high-cupped *E. tuberculatus* forms are closer to *E. crassus* in general calyx proportions than to *E. elrodi*; the synonymy of *E. tuberculatus* and *E. elrodi* is regarded herein as tentative.

Rowser (1932, pp. 102-134) recognized 19 species of *Eucalyptocrinites* from the Silurian rocks of Iowa, 11 of which are from the “*Cyrtia* beds,” the Hopkinton Dolomite. Over 500 specimens of *Eucalyptocrinites* from the “*Cyrtia* beds,” including Rowser’s original material, were examined in this study in order to define the range of variation exhibited within the sample. Based on criteria exclusive of ornamentation the “*Cyrtia* bed” sample was closely comparable to many specimens described from the Racine Dolomite (Wisconsin, Illinois). Thirteen species of *Eucalyptocrinites* from the Racine Dolomite were recognized (Hall, 1861; Weller, 1900) based largely on isolated specimens with little or no consideration given to the range of variation within the collections. However, transitional forms are noted that link together several of the Racine “*species*” into a continuous series. Weller (1900, p. 113) recognized a gradational series connecting *E. depressus*, *E. ornatus*, and *E. asper*: “the internal casts of all three of these species show considerable variation, and in a large collection of specimens almost a complete series, with all intermediate forms, may be selected.” The separation of such a sample exhibiting a complete range of variation into several distinct “*species*” is an arbitrary procedure, and serious taxonomic problems can arise when dealing with the intermediate forms of the series. For the purposes of this report a sample that reveals a continuous range of variation for all features that vary within the sample will be regarded as a single species.

The preservation of the Hopkinton Dolomite material is generally poor, although variation in dorsal cup shape and the degree of basal invagination is observable on about half of the 500 specimens. Based on qualitative comparisons, a complete range of variation in the degree of basal invagination is noted for all specimens with the exception of 15 specimens with a broad base excavated to a depth equal to the entire height of the dorsal cup and with the RR completely invaginated; this group of specimens is referred to *E. depressus*. The gradation of *E. depressus* into *E. ornatus* noted in the Racine Dolomite by Weller (ibid.) is not observable in the Hopkinton Dolomite sample, and *E. depressus* is recognized as a distinct species in the Hopkinton until transitional forms are found from the same horizon.

The variation in cup shape is observable on 222 of the remaining specimens; the dorsal cup shape varies between conical, subglobose, subturbinate, turbinate, subhemispherical, and low saucer-shaped (see Text-fig. 18). A quantitative measure of the dorsal cup shape is approximated by measurements of the cup’s height and width. A bivariate plot of these measurements is shown in Text-fig. 19; a wide range of variation is noted. The plots are clustered around two regression lines with significantly different slopes. A histogram plot of cup shape vs. frequency (cup shape is expressed as the ratio of height/width) reveals complete gradation of cup shape between 0.36 and 0.98 for the majority of the specimens. The lack of a natural break within this series and the bell-shaped frequency distribution is interpreted as representing the total range of dorsal cup variation exhibited within a single species; this abundant species is regarded as *E. sp.* (cf. *E. ornatus*). Rowser (1932) using size, dorsal cup shape, and degree of basal invagination erected seven new species without considering the range of variation of the diagnostic features within his Iowa collections. These seven “*species*” all fall within the range of variation that we are considering to be a single species.

*Eucalyptocrinites* from the Racine Dolomite are closely comparable to the Hopkinton specimens in their range of variation; *E. egani*, *E. crassus* (sensu Weller, 1900), *E. turbinitus*, and *E. ornatus* all fall within the range of variation noted for the single Hopkinton species, *E. sp.*, as indicated in Text-fig. 19. A number of low saucer-shaped dorsal cups of *Eucalyptocrinites* plot as a distinct group on both the bivariate plot and the histogram; these forms are recognized as a distinct species conspecific with the Racine Dolomite form, *E. inornatus*. Weller (1900, p. 116) believed *E. inornatus* to be readily separable from all other species in the Racine.

Collections of *Eucalyptocrinites* from the Racine Dolomite (Wisc.,...
EARLY SILURIAN CAMERATE CRINOIDS OF EASTERN IOWA

1. [Image 1]
2. [Image 2]
3. [Image 3]
4. [Image 4]
5. [Image 5]
6. [Image 6]
7. [Image 7]
8. [Image 8]
9. [Image 9]
10. [Image 10]
11. [Image 11]
12. [Image 12]
13. [Image 13]
14. [Image 14]
15. [Image 15]
16. [Image 16]
17. [Image 17]
18. [Image 18]
19. [Image 19]
20. [Image 20]
21. [Image 21]
22. [Image 22]
23. [Image 23]
24. [Image 24]
25. [Image 25]
III.), the Brownsport Formation (Tenn.), and from Gotland (Sweden) have not been defined in terms of the total range of variation noted, and the validity of many of the defined species must remain in question until such comparisons are made. Known collections of Eucalyptocrinites (Hopkinton Dolomite, Waldron Shale) show features that vary within a continuous series. Variable features such as size, cup shape, degree of basal invagination, ornamentation, loss of one or more IBr, and IBr1 in lateral contact should not be used to diagnose a species unless such features can be demonstrated to vary within a definable range of values distinct from that noted in other species of the genus.

Eucalyptocrinites first appears in four late Llandoverian formations in North America: the Jupiter Formation (Anticosti Island), the Brassfield Limestone (Ohio), the Joliet Dolomite (Illinois), and the Hopkinton Dolomite (Iowa)(Witzke et al., 1979). Eucalyptocrinites probably arose directly from Arachaeocrinites during the late Llandovery. The development of an invaginated base accompanied by rapid expansion of the tegmen partitions and anal tube in Arachaeocrinites would produce forms assignable to Eucalyptocrinites. The separation of adjacent IIBr1 and the development of an elongate anal tube above the platform of the tegmen were achieved early in the evolution of Eucalyptocrinites. The loss of one primibrach in one or more rays is a feature common in many species of Eucalyptocrinites, a characteristic already evident in some Hopkinton specimens but more common in Devonian collections (Ubags, 1978). Geologically younger Eucalyptocrinites generally exhibit a loss of the elongate anal tube above the tegmen platform and the development of more massive tegmen partitions (e.g., E. milliganae, E. rosaceus). Eucalyptocrinites is among the most widespread, long-ranging, and abundant of all Paleozoic crinoids. Its known geologic range is from Late Llandoverian to the base of the Emsian (E. proboscidialis Miller, 1882) and extends into the Emsian (E. inornatus Miller, 1880). Eucalyptocrinites proboscidialis by a broadening of the dorsal cup with subsequent separation of adjacent IIBr1 (primibrach comes in contact with IIBr) and by invagination of the flat base. E. proboscidialis is noted herein for the first time from the Racine Dolomite of Racine, Wisconsin.

Material: The holotype is numbered 13867 (Ohio State Univ. Orton Museum). The Iowa specimens are numbered SUI 31655, 31656. Three Racine Dolomite specimens are numbered SUI 39903.

Horizon and Locality: The holotype is from the Cedarville Dolomite (probably Wenlockian) at Pontiac, Ohio. The Iowa specimens are from the “Cyria beds” at Loc. 10. The Wisconsin specimens are from Racine Dolomite (Wenlockian) at “Racine.”

Eucalyptocrinites depressus S. A. Miller, 1880
Plate 4, Figs. 12-14

Diagnosis: Calyx subcylindrical; dorsal cup twice as wide as high; basal concavity deeply and broadly funnel-shaped; basal and radial plates completely invaginated at base; IBr1 and IBr may be slightly invaginated; plates convex, their surface ornamented with rugose markings.

Discussion: E. depressus represents the extreme in basal invagination noted for the genus. Weller (1900, p. 113) noted gradation between E. depressus and E. ornatus in the Racine Dolomite, although this gradation has not yet been observed in the Hopkinton collections. Three specimens (SUI 39892) are not as deeply excavated as the others; with further material the transition observed by Weller may also be observed in the Hopkinton Dolomite. Until the transition is demonstrated, E. depressus will be regarded as a distinct species in the Hopkinton. SUI 31670 clearly reveals that the plates of E. depressus are ornamented with coarse rugose markings, a feature that remained indeterminate in the Racine specimens (Weller, 1900, p. 114, “surface apparently rugose”).

Material: Fifteen specimens are numbered SUI 31642, 31668, 31669 (5), 31670, 39891, 39892 (3), 39893, 39899 (2).

Horizon and Locality: “Cyria beds;” Localities 1, 2, 3, 7, 12 (SE sec. 35), 43.

Eucalyptocrinites inornatus Weller, 1900
Plate 4, Figs. 17, 18; Text-fig. 19

Diagnosis: Dorsal cup greatly depressed, low saucer-shaped, more than twice as wide as high; basal concavity small and shallow; plates flat, unornamented.

Discussion: Hopkinton Eucalyptocrinites with greatly depressed cups plot as a distinct group of specimens on the bivariate plot with no overlap for those specimens with a cup width greater than 17 mm. These specimens are assigned to E. inornatus. Smaller specimens on the bivariate plot (less than 17 mm width) are more tightly spaced, and separation into two distinct groupings (E. inornatus, E. sp.) is more difficult. The histogram shows three specimens that appear to grade dorsal cup shape between E. sp. and E. inornatus. Some specimens included in E. inornatus (SUI 39896, 39898) are reminiscent of low-cupped E. sp. (e.g., SUI 31625), and a transition may exist between the two forms. However, the rise in frequency on the histogram between 0.31 and 0.35 may suggest that there is a distinct but smaller population present. The smaller population clustered around 0.33 on the histogram is assigned to E. inornatus. Weller (1900, p. 116) regarded E. inornatus as a distinct group of low-cupped, smooth-plated Eucalyptocrinites in the Racine Dolomite, and he did not note any transition between this group and other forms of Eucalyptocrinites.

Material: Thirty-six specimens are numbered SUI 31626 (11), 31636 (2), 31637, 31639 (2), 31641 (2), 31673 (3), 31675, 39894, 39896 (4), 39898 (5), 39897 (2), 39895 (2).

Horizon and Locality: “Cyria beds;” Localities 1, 2, 7, 10, 15, 42 (sec. 11).
Fig. 18. Silhouettes of Eucalyptocrinites dorsal cups. A-L are specimens of E. sp. from the Lower Silurian, Iowa. M-P are specimens chosen to illustrate some of the variation noted in populations of E. crassus from the Waldron Shale, Indiana and Tennessee (from Kesling et al., 1973); these are included for comparison. A) SUI 39874, B) SUI 39877, C) SUI 31666, D) SUI 39885, E) SUI 39884, F) SUI 39887, G) SUI 39878, H) SUI 39885, I) SUI 31645, J) SUI 39883, K) SUI 39882, L) SUI 31621. The classification of Eucalyptocrinites used in the Racine Dolomite sample by Weller (1900), if applied to the Iowa material, would probably assign A, B, and E to E. crassus, C and D to E. egani, F and G to E. turbinatus, and H-L to E. ornatus. In this study A-L are assigned to a single species. Approximately to scale.

Eucalyptocrinites sp. (cf. E. ornatus Hall, 1861)

Diagnosis: Dorsal cup varies in shape between conical, turbinate, and low saucer-shaped; dorsal cup height/width ratio varies 0.36 to 0.98; basal concavity shallow to deep; plate surfaces ornamented with delicate sculptured ridges.

Discussion: A continuous range of variation in dorsal cup shape and degree of basal invagination within the Hopkinton Eucalyptocrinites collection is used to define a single species, E. sp. The collection shows similarities to E. ornatus, E. turbinatus, E. egani and E. crassus (sensu Weller, 1900) from the Racine Dolomite, although none of the diagnostic features of these species define the full range of variation noted in the Hopkinton sample. The great majority of the specimens are similar in general form to E. crassus; however, the presence of a delicate sculptured ornamentation (SUI 39879) precludes the assignment of the Hopkinton specimens to E. crassus (type from Waldron Shale), a form with smooth plates. SUI 39879 and 31622 external molds reveal the aboral nerve tract system at the base of the cup, an unusual state of preservation. E. sculptilis (Springer, 1926) from the Decatur Limestone has delicately sculptured plates, but E. sp. from the Hopkinton has an even finer and more delicate ornamentation. The delicate ornamentation of E. sp. is preserved on only one specimen (SUI 39879), all other specimens have recrystallized external molds that do not preserve any delicate external markings. Such delicate markings would probably be obliterated in the extensively recrystallized Racine Dolomite sample, and it will remain uncertain if the Racine forms also possessed similar markings.

Until the Racine sample is re-investigated, the total range of variation in dorsal cup shape defined, and synonymies of the included species discussed, the Hopkinton sample will remain in open nomenclature (E. sp.). If the range of variation in the Racine sample is found...
to be similar to that noted in the Hopkinton, the Hopkinton collection (E. sp.) should probably be referred to E. ornatus (Hall, 1861), the oldest described species of the series. Eucalyptocrinites, as exemplified by E. sp., exhibits one of the highest levels of intraspecific variation noted in any Paleozoic crinoid group. The reasons for the wide range of variation are unclear, although external environmental controls acting on the population during ontogeny are invoked as a major controlling factor in determining the dorsal cup shape of the individual crinoids. Kesling et al. (1973, pp. 49-50) invoked transportation of young crinoids from one environment to another in an effort to explain the wide variation in cup shapes generated during the ontogeny of the individual crinoids. A few specimens of E. sp. are noted adjacent to bioherms in coarse crinoidal dolomites (SUI 39878), although the vast majority of the specimens are found in the typical 'Cyrtia bed' level-bottom paleocommunities associated with fenestellids, stricklandids, and numerous other echinoderms and brachiopods. It seems doubtful that transportation from one environment to another can be invoked to explain the variation in dorsal cup shape noted in the Hopkinton sample.

**Material:** Four hundred eighty-six specimens are numbered 3482 (10), 31605, 31606 (22), 31608 (17), 31609 (2), 31610 (7), 31611 (2), 31616 (31), 31620, 31621 (90), 31622, 31623, 31625, 31630, 31640, 31645, 31646, 31647 (28), 31648, 31666 (16), 31667 (5), 31671 (10), 31672, 31674, 39783 (106), 39874 (8), 39876 (6), 39877 (25), 39878, 39879, 39880 (30), 39881 (4), 39882 (9), 39884 (7), 39885 (9), 39886, 39887 (6), 39888, 39889 (9), 39892.

**Horizon and Locality:** Adjacent to Bioherms at Locality 33. ‘Cyrtia beds’ at Localities 1, 2, 4, 6, 7, 10, 15, 18, 30, 34, 42 (SW sec. 10; sec. 11; SW sec. 35).

**Genus CALLIOCRINUS d’Orbigny, 1850**

**Type species:** Eugeniocrinites ? costatus Hisinger, 1837; M

**Diagnosis:** A genus of the Eucalyptocrinitidae with two primibrachs per ray; BB and proximal portion of RR gently to deeply invaginated at base of dorsal cup; 20 vertical partition plates restricted to the lowermost circle of plates on the tegmen which do not form alcoves for complete arm enclosure; four fourth level (uppermost) tegmen plates enclose a quadrangular anal opening, often extended horizontally into wing-like extensions forming a broad umbrella-like covering over the arms; calyx plates ornamented with spines, nodes, or ridges.

**Discussion:** The twenty small vertical tegmen partitions of Callicrinus contrast markedly with the 10 large tegmen partitions of Eucalyptocrinites. With few exceptions (e.g., E. depressus), Calliocrinus has a more deeply excavated basal concavity than Eucalyptocrinites; the plates of Calliocrinus are ornamented with prominent spines, nodes, or ridges whereas Eucalyptocrinites has smooth, gently sculptured, or gently nodose plates. Eucalyptocrinites may have one or two primibrach per ray, all Calliocrinus have two primibrachs per ray, and Chicagocrinus has only one reduced primibrach per ray. The dorsal cup plate arrangement is remarkably similar in all members of the Eucalyptocrinitidae with the exception of the primibrach series in the North American Callicrinus-Chicagocrinus lineage. Most Calliocrinus possess quadrangular IBr1 and pentagonal IBr2; a trend toward reduction and loss of one primibrach is first evident in Callicrinus primibrachialis in which the first primibrach is reduced to a small ovoid rudimentary plate surrounded by the IBr2 and R (Busch, 1943). The continued reduction of IBr2 and the loss of IBr1 would lead toward the extreme condition noted in Chicagocrinus in which the remaining primibrach is reduced to a small triangular plate and the first secundibrachs share a suture with the radials (see Text-Figure 20).

Many species of Calliocrinus have adjacent IBr1 in lateral contact, a condition aligning Calliocrinus more closely with Archaeoalyptocrinites than Eucalyptocrinites. Callicrinus probably originated in North America from a form like Archaeoalyptocrinites nodosus during the late Llandoverian. The oldest Calliocrinus are noted from the Hopkinton Dolomite (late Llandoverian). By the Wenlockian Calliocrinus had spread to Europe. The last occurrence of Calliocrinus is noted from Emsian (L. Devonian) rocks in the Urals.

The development of umbrella-like winged terminal plates surrounding the anal vent in Calliocrinus is among the most curious of features developed in any crinoid group. The functional significance of this feature is unclear. In the closely related genus, Eucalyptocrinites, tegmen partitions allowed for enclosure of the arms which apparently functioned to protect the pinnate arms during periods of quiescence. The winged terminal plates in Calliocrinus could also have served as a protective cover over the arms; small retractive slots at the base of the tegmen could help protect the arm bases. Additionally, the winged

![Fig. 20. Evolutionary trend in the primibrach series of the North American Callicrinus-Chicagocrinus lineage. Radials black; primibrachs numbered; first secundibrachs unnumbered. A) 'Typical' Callicrinus (e.g., C. cornutus), B) Calliocrinus primibrachialis, C) Chicagocrinus inornatus.](https://scholarworks.uni.edu/pias/vol88/iss3/3/32)

terminal plates could have created a current-baffling effect allowing for more efficient feeding. Welch (1978) described tegmen wing plates in the Carboniferous genus *Pterotocrinus* which he suggested served a dual feeding and protective function, and the bizarre tegmen of *Calliocrinus* with winged terminal plates may have served a similar dual function. During feeding periods *Calliocrinus* must have held its arms out laterally; large spines, such as those noted in *C. murchisonianus* and *C. longispinus*, could serve to protect or support the laterally extended arms at that time. If *Eucalyptocrinites* and *Calliocrinus* developed these unique tegmen features for arm protection, it remains uncertain as to why other successful crinoid groups with exposed arms found it unnecessary to have analogous structures.

Isolated umbrella-like terminal plates were first noted by Hall (1867) from Wisconsin who named them *Cryptodiscus*. The affinities of the plates remained unclear until Weller (1897) found the terminal plate positioned on a *Calliocrinus*-like anal tube from Racine, Wisconsin. Weller (1900, p. 122) also suggested that some of the terminal anal discs may belong to *Chicagocrinus*. Weller (1897, 1900) assigned six new species from the Racine Dolomite to *Calliocrinus* based solely on isolated terminal anal discs. All six species are regarded herein as tentative since "two names may be given to two distinct portions of the same species, one to the dorsal cup and one to the terminal anal disc" (Weller, 1900, p. 122). The dual nomenclature that can result is highly undesirable, and an effort to correlate isolated anal discs with associated *Calliocrinus* dorsal cups should be made. In the Hopkinton Dolomite the terminal anal discs are found in strata in which *Calliocrinus longispinus* dorsal cups are also found; the discs are tentatively assigned to that species.

**Calliocrinus longispinus** Weller, 1900  
Plate 5, Figs. 8-10

**Diagnosis:** Dorsal cup with deep basal excavation whose outer margin is roughly pentagonal; radials, first interbrachs, and lowest most circle of plates on tegmen produced into long spines; interspinal nodes developed on cup; terminal anal disc probably present.

**Discussion:** The Hopkinton specimens appear to be conspecific with *C. longispinus*, a species originally described from the Racine Dolomite. However, the Hopkinton specimens preserve structures not noted on the Racine specimens; the lowest most circle of tegmen plates bears spines (SUI 39900) and interspinal nodes are present on the cup (SUI 31680). *C. longispinus* closely resembles *C. murchisonianus* from Gotland but differs in possessing interspinal nodes and a more deeply excavated base. *C. cornutus*, also from the Racine Dolomite, is closely similar to *C. longispinus* but has shorter spines that are developed only on the radial plates (Weller, 1900, p. 119). Busch (1943, p. 109) proposed the synonymy of *C. costatus* (Gotland) with *C. cornutus* (Racine); this synonymy is regarded herein as unlikely since *C. costatus* is ornamented with low ridges whereas *C. cornutus* has spined and nodose plates.

Two types of terminal anal discs are found at the same horizon as *C. longispinus*, and these are tentatively included in the species. Using a dual nomenclature, the discs would be referable to *C. hydei* and *C. corrugatus*. Weller (1900) described from the Racine Dolomite six species of *Calliocrinus* based on terminal anal discs and three species based on dorsal cups. It seems highly likely that one species of *Calliocrinus* could have more than one type of anal disc. The radial spines are directed upward forming a 25° angle with the base of the cup. SUI 39900 has a cup 27 mm wide with radial spines in excess of 30 mm long. Two other dorsal cups (SUI 31680, 31678) have a width of 25 and 20 mm respectively. Two terminal anal discs (SUI 31676, 31684) have a minimum width of 47 and 55 mm respectively.

**Material:** Dorsal cups and calyces are numbered SUI 31678, 31680,
Devonian genera (*Amblacrinus, Cantharocrinus*, and *Culicocrinus*). The third trend, also characterized by displacement of the iBrr from the tegmen by the orals, exhibits additional developments such as a more sharply differentiated and loosely-sutured tegmen and a single primibrach per ray (Frest & Strimple, 1977a). This third group, the *hirneacrinids*, includes the Silurian genera, *Hirneacrinus* and *Hagnocrinus*. Another group of small Silurian platycrinitaceans, probably derived from a *hirneacrinid* stock, was assigned to a distinct family, the *Prokopelocrinidae*, by Frest and Strimple (1977b, 1980). The tegmen of the *prokopelocrinids* is unknown, although, like the *hirneacrinids*, the distal margin of the RR extends onto the oral surface (ibid., p. 145).

*Theleproktocrinus* represents a highly successful patellioctocrinid derivative that was probably directly ancestral to later hapalocrinids and *hirneacrinids*. The origin of the *Platyctrinidae* is presently not as clear; the presence of axillary ambulacrals on the Ludlovian *"Culicocrinus" spinosus* from Tennessee (Springer, 1926) seems to suggest that the platycrinids diverged from a *hapalocrinid* stock sometime in the latter half of the Silurian.

**Genus THELEPROKTOCRINUS** n. gen.

**Type species:** *Theleproktocrinus davidsoni* n. sp.

**Diagnosis:** Small basal aligned with CD interray. Two primibrachs fused into cup above RR and between iBrr. Tegmen gently convex; distal half of iBrr incorporated into tegmen, followed by 2 interambulacral areas. Primanal distally incorporated into tegmen, followed by 3 interambulacral areas (iBrr) in next range, with 3 plates in next range adjacent to anus. Anus protruberant. Ambulacra suprategminal, covered by alternating ambulacrals. 10 arms.

**Discussion:** *Theleproktocrinus* is most similar to *Lyonicrinus* (Brownsport Pm., Tennessee) from which it differs in having the proximal portions of the iBrr incorporated well into the cup, in adambulacral areas, and in the arrangement of the plates in the posterior interambulacral area. Gerontic individuals of *Theleproktocrinus* are the largest known hapalocrinids.

FIG. 22. **Oral view of Theleproktocrinus davidsoni. Anus shown in black.**

**Fig. 23. Scatter plot (height vs. width) of measurable dorsal cups of Theleproktocrinus davidsoni.**

**Derivation of name:** Thele (Greek), nipple-like protruberance; prokto (Greek), anus ("crinoid with protruberant anus").

**Theleproktocrinus davidsoni** n. sp.

**Plate 5, Figs. 11-19; Text-figs. 22,23**

**Description:** Calyx subglobose, height and width roughly equal, widest at distal level of RR. Three basals: two large pentagonal BB are second largest plates in calyx; one small quadrangular basal aligned with CD interray; basal pentagon occupies about two-thirds total cup width. Radials very large, roughly equidimensional, about one-half as high as calyx, in contact all around; RR hexagonal, distal margin concave. First primibrachs quadrangular, proximal margin in contact with RR convex; iBr1 over twice as wide as high. Primaxil (iBr2) incorporated in cup, similar in size to iBr1, supporting two arm facets; no secundibrachs incorporated into cup. Proximal interbrachs visible in lateral and oral view, being eliminated from cup onto tegmen; iBrr hexagonal (or octagonal if lateral margins of iBrr and iBr2 are not aligned), higher than wide, next in size to BB. Tegmen gently convex; interambulacral areas composed of two pentagonal interambulacral areas (displaced iBrr) following iBrr, each in contact with ambulacra, and one small quadrangular plate resting between adjacent ambulacra here termed the orals. All interambulacral areas of equal width; posterior interambulacral area differentiated; primanal heptagonal, occupying a position analogous to iBrr, bearing 3 interambulacral plates (displaced iBrr), two hexagonal plates adjacent to ambulacra, one rectangular plate in series above primanal. Three plates in next range adjacent to anus; 2 small quadrangular plates adjacent to ambulacra and a central hexagonal interambulacral in series with anus above rectangular plate. Anus large, subcentral, protruding on internal molds, in contact with adjacent ambulacra. Ambulacra prominent, suprategminal, protruding laterally on internal and external molds, bifurcating at about one-half their total length. Ambulacra hexagonal, alternating in two rows before bifurcation; after bifurcation ambulacra smaller, alternating. Surface of plates smooth. Ten arms of unknown structure. Lumen pentalobate.
Size variation noted (height exclusive of anal protrubance × maximum width): smallest specimen, 7 mm × 7.6 mm; largest specimen, 46 mm × 47 mm.

Discussion: Gerontic Theleproktocrinus davidsoni reach exceptionally large sizes and, along with Dimorocrinites (Eucrinus), are the largest crinoids in the "Cyclocrinites beds." A scatter-plot of the measurable specimens (Text-figure 23) reveals a linear trend in the growth-series; Theleproktocrinus maintained the same general shape throughout the series, from the smallest specimens to the largest ones. The individual plates of Theleproktocrinus (simplified cup geometry with RR & BB predominating) maintained their same proportions during growth unlike the mode of growth noted, for example, in Eucalyptocrinites (Macurda, 1968; Kesling et al., 1973), Eopatelliocrinus, and Macrostylocrinus (Brower, 1973). Wachsmuth and Springer (1987, p. 735, pl. 75, fig. 14) illustrated a specimen of T. davidsoni from "Maquoketa, Iowa" and believed the specimen represented a Culletocrinus or Marsupiocrinus.

Genus LYONICRINUS Springer, 1926

Type species: Cocconocrinus baccus Roemer, 1860; OD

Discussion: The protruberant anus of Lyonsocrinus is similar to that noted in Theleproktocrinus. The similarities between Lyonsocrinus and "Cyttarocrinus" jewetti are striking; the latter species, a form significantly different from the type species of Cyttarocrinus, should probably be moved to another genus (Koenig, 1965, p. 412; Ubaghs, 1978, p. 514).

LYONICRINUS sp.

Plate 5, Figs. 21, 22

Description: Three BB, 1 large, 2 small. Radials largest plates in cup. Primibrachs on lobes, not rigidly incorporated into the calyx. Interbrachs largely excluded from cup, although the proximal portion of the interbrachs can be seen on two of the three specimens in the notch between adjacent RR at the proximal margin of the cup. Tetgmegn unknown. Cup measurements (height × width): 8.5 mm × 11.8 mm, 7.5 mm × 8.2 mm, 5.7 mm × 7.8 mm.

Discussion: Until the tegmen of the Hopkinton specimens becomes known, the assignment of the species to Lyonsocrinus is tentative. The dorsal cup of the Hopkinton species is most similar to Lyonicrinus baccus, Brownsport Fm. of Tennessee. The presence of Lyonsocrinus in the "Cyttia beds" of Iowa indicates that a considerable advancement in haplocrinid evolution (exclusion of iBBr from cup) had occurred between the mid Late Llandovery (Theleproktocrinus) and C. Late Llandovery.

Material: Three specimens are numbered SUI 39974.

LYONICRINUS sp.

Plate 5, Figs. 20

Discussion: Fresn and Strimple (1977a) briefly considered the placement of a small collection of platycrinacean crinoids from Locality 15;

All are dolomite internal casts of a subconical crinoid with a simple plate configuration (three unequal basals and five radials); beyond that little can be established from the available material. The plates of the oral surface are unknown; the assignment to Hagnocrinus is based mostly on the resemblance of these casts to the internal cast of Platycrinus augusta (= Hagnocrinus augusta (Slocum) Fresn and Strimple, n. comb.

Hagnocrinus ‘‘occupies a position among the Platycrinacea closely analogous to that of the Marsupiocrinidae in the Patelliocrinacea’’ (ibid.). The abundance at some localities (e.g., Loc. 15) of isolated conical basal circles indicates that the basal plates were tightly fused together and did not disarticulate as quickly as the remainder of the calyx. Tightly fused basal circles are also a characteristic feature of the Marsupiocrinidae.

Material: Primary reference specimens numbered SUI 39926 (5) and 39975 (int., ext.); additional specimens numbered SUI 31735, 39927 (30).

Hagnocrinus: ‘‘Cyttia beds;’’ Localities 15 and 42 (sec. 10).

REFERENCES


Foster, A. F., 1920, Racine and Cedarville cystoids and blastoids with notes on other echinoderms: Ohio Jour. Sci., v. 21, p. 33-82.


Hall, J., 1867, Account of some new or little known species of fossils from
EARLY SILURIAN CAMERATE CRINOIDS OF EASTERN IOWA


WELCH, J. R., 1978, Flume study of simulated feeding and hydrodynamics of a Paleozoic stalked crinoid: Paleobiol., v. 4, p. 89-95.

WELLER, S., 1897, Cryptodiscus, Hall: Jour. Geol., v. 5, p. 803-808.


APPENDIX: LOCALITY REGISTER

All locality numbers mentioned in the text are listed below according to county. The beds cropping out at each locality are recorded as follows: P (Pentamerus beds), Cc (Cyclocrinites beds), F (Favorites beds), B (bioherm and upper quarry beds), Cr (Cyrtia beds), Pd (Pentamorinde beds).

Cedar County
1. NW 4 sec. 13, T82, R1W, cliffs and small abandoned quarry along Wapsipinicon River in county park; Cr.
2. NW 4 sec. 5, T82, R1W, the "Orelup locality," a small quarry; Rowser (1929, p. 29) recorded it in NW 4 sec. 6; Cr.
3. NW 4 & SW 1/4 sec. 10, T82, R1W, small quarry and roadcut; Cr.

Clinton County
4. SE ¼ NW 4 sec. 8, T83, R2E; Elwood Quarry; B (bioherm), Cr.
5. NW 4 NE ¼ sec. 17, T83, R2E; Wirth Quarry; Cr, B, Cr.
6. NW 4 SW 1/4 sec. 2, T81, R3E; Behr Quarry; B, Cr.
7. c. sec. 1, T80, R5E; unknown outcrop; Cr.
8. n. sec. 34, T83, R4E; abandoned quarry 1 mi. SW of Charlotte; Cr.
9. nd Ny. sec. 34, T83, R4E; abandoned quarry 1 mi. SW of Charlotte; Cr.

Delaware County
10. "Clinton;" unknown locality labels for specimens found in the vicinity of Clinton; Cr, Cr.

Dubuque County
11. SE ¼ SE ¼ sec. 23, T89, R3W, Kapfh Quarry; Cr, F.
12. NE ¼ NW 4 sec. 36, T90, R6W; Sedgwick Quarry; Cr, F.

Jackson County
13. c. sec. 24, T85, R2E; U.S. 61 roadcut in Fulton; P, Cr.
14. NE ¼ SE ¼ sec. 3, T84, R1E; roadcut and river bluffs; Cr, F, Cr, Pd.
15. NW 1/4 SE ¼ sec. 20, T84, R2E; Joines Quarry; Cr, F.
16. SE ¼ NW 4 sec. 12, T84, R2E; Hurstville Quarry; P, Cr.
17. NW 1/4 NE ¼ SE ¼ sec. 26, T86, R3E; Rowbin Quarry; Cr, F.
18. NE ¼ SE ¼ sec. 31, T89, R2W; roadcut on U.S. 20 in Dyersville; Cr, F.
19. "roadcut on Hwy. 136 1.3 miles south of Dyersville;" a D. B. Davidson label; Cr.

Jones County
20. NE ¼ NE ¼ sec. 14, T86, R3W; Farmer's Lime Quarry; P, Cr, F.
21. SE ¼ sec. 7, T85, R2W; Willins Quarry; B, Cr.
22. SW 1/4 sec. 32, T86, R2W; river bluffs, Picture Rock Park; Cr, F, B, Cr.
23. SE ¼ NE ¼ sec. 22, T86, R3W; River quarry near Monticello; Cr, F.
24. NW 1/4 NW 4 sec. 24, T86, R4W; Monticello Quarry; B (bioherm), Cr.
25. "8 miles northwest of Monticello;" unknown locality label; B and/or Cr.
26. sec. 23, T86, R3W; unknown outcrop; Cr.
27. NW 1/4 sec. 4, T85, R3W; Hwy. 151 roadcut; B (bioherm), Cr.
28. sec. 27 & 33, T86, R3W; unknown outcrops; Cr, B.
29. secs. 19 & 36, T86, R3W; unknown outcrops; Davidson collection; Cr.
30. secs. 9, 10, 11, 25, 26 & 35, T84, R1W; numerous natural outcrops and roadcuts; Cr.
31. NW 4 sec. 33, T84, R1W; Wyoming Quarry; bioherms.