EXPLOSIVE EVOLUTIONARY DIFFERENTIATION OF UNIQUE GROUP OF MISSISSIPPIAN-PENNYSYLVANIAN CAMERATE CRINODS (ACROCRINIDAE)

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ABSTRACT

Crinoids classed as constituents of the family Acrocrinidae are distinguished from all other Camerata, as well as representatives of remaining subclasses, in having circlets of supplemental calyx plates between the bipartite basals and ring of radials and single primanal at summit of the calyx. The supplemental plates, designated as intercalaries, range in number from six to 600 or more. Analysis of their arrangement, combined with other characteristics, furnishes morphological grounds for differentiation of several genera instead of a single one (Acrocrinus), which until now has been considered to be the sole generic component of the family. All of the newly recognized acrocrinid genera and seven new species assigned to three of them are determined on seemingly firm and significant distinctions. The whole assemblage demonstrates remarkable evolutionary changes along different lines, which are expressed in calyx shape, attitude of the basal plates, number and positions of the arms, features of the tegmen, and especially by an explosively rapid increase in number of intercalary plates to a Late Mississippian peak, great decline in the Pennsylvanian, and by diverse patterns of distalmost intercalaries. Two subfamilies are recognized but their interrelations and phylogenetic lines are very obscure.

INTRODUCTION

Around the middle of the last century, approximately 125 years ago, some unique fossil crinoids were discovered by L. P. YANDELL and B. F. SHUMARD in western Kentucky (Grayson County) about 75 miles southwest of Louisville. They were obtained from strata then called Lower Carboniferous and now classed as Upper Mississippian (Chesteran). Among these fossils were at least one flattened incomplete crown with a short section of attached stem and specimens consisting of parts of calices. Later deposited in a museum in Louisville, the calyx with remnant portion of arms has a height of 80 mm. (3.25 in.) and maximum calyx width of 30 mm. (1.2 in.). Based on comparison with other complete crowns, this specimen had an original height of at least 160 mm. (6.5 in.). A platyceratid snail 40 mm. tall and nearly as wide at its base as the entire space between arm bases is fixed to the crinoid's tegmen.

The most distinctive feature of the calyx is the construction of its side walls, formed by hundreds of small polygonal plates arranged in well-defined circlets, instead of the very modest number of calyx plates found in most crinoids. Next beneath the branched free arms in each of the five rays is a very wide, low radial plate, and although not shown in the first-found flattened crown, a sixth plate shaped like the radials but without attached arms is interposed in the radial circlet. This plate now is designated as primanal.

At the bottom of the calyx are two relatively large basal plates with steeply upsloping outer margins. They are equal in size and divided by a straight suture. The small polygonal plates between the
basals and radials are called intercalaries. They are arranged in approximately 20 to 25 circles and in aggregate number are roughly 600 to 700. The round stem is composed of low circular discs.

The previously mentioned specimen with attached gastropod was illustrated by Yandell & Shumard in 1847 (pl. 1, fig. 3) without an accompanying name and without description, except for mention (p. 25) of its extraordinarily numerous calyx plates. Eight years later, Yandell (1855) published a larger and improved drawing of the specimen figured in the 1847 paper and with it a diagnosis of the crinoid as representative of a new genus named Acrocrinus. The type species (by monotypy) was designated A. shumardi. Affinity of Acrocrinus with Platycrinus (recte Platycriinites) was suggested because of its bipartite basal circlet, although the three-basal circlet of Platycriinites is not at all comparable to that of Acrocrinus. No family assignment for the new genus was suggested.

A curious irrelevant item is the statement by Yandell (p. 136) that the large gastropod fastened to the tegmen of the crinoid is truly recognizable as prey of the crinoid “in a position to have been grasped by the arms of the living animal . . . [which] was probably devouring the shell-fish at the time when it perished.” This was thought to be borne out by the observation that “we have found numerous specimens of encrinites with univalve mollusca in a similar position”—observation correct but interpretation wrong, for no one doubts that the gastropod-crinoid association is explained by the gastropod’s selection of a crinoid host which after attachment of the snail to its tegmen willy-nilly yields its fecal waste for sustenance of the gastropod (Bowszer, 1955).

In 1858, Hall (p. 690, pl. 25, fig. 9a-b) figured and very briefly described a crinoid “with base divided on one side” and superjacent lower sides of the calyx composed of numerous tiny polygonal plates not arranged in regular circles. Because of incompleteness of this fossil, the nature of the summit portion of the calyx, as well as that of the arms and stem was unknown. Hall assigned the specimen to a new species named Acrocrinus urnaeformis, which, despite recognition by Wachsmuth & Springer (1885, p. 125) and subsequently by Springer (1926, p. 44), is considered insufficiently distinct from A. shumardi for treatment other than as a synonym of the latter species (Wachsmuth & Springer, 1897, p. 806; Bassler & Moodey, 1943, p. 266). A. urnaeformis occurs in Upper Mississippian (Chesterian) strata now classed as Paint Creek Formation, in Pope County, southernmost Illinois.

The family Acrocrinidae was proposed by Wachsmuth & Springer in 1885 (p. 120) for reception of the single genus, Acrocrinus. These authors reaffirmed the family-group assemblage in 1897 (p. 803) with an accompanying diagnosis which noted its morphological resemblance to the Hexacrinidae except for possession of numerous circles of intercalary plates. The acrocrinids were presumed to be descendants of hexacrinid ancestors. Bather (1899, p. 921) mentioned the Acrocrinidae in his phylogenetic classification of Echinozoa but did not cite them in The Echino-derma (Bather, 1900). Moore & Landon (1943, p. 96) published a characterization of the family and of Acrocrinus, concluding that crinoids of this group were derived from the Dichocrinidae, which also have two equal basalas. Urahs (1953, p. 740-741) placed Acrocrinus in a subfamily (Acrocrininae) of the Dichocrinidae, along with genera grouped in the Dichocrininae and a newly defined subfamily named Talarocrininae.

Studies of new Pennsylvanian acrocrinids planned for inclusion in two papers on assemblages of Morrowan and Missourian crinoids have led us to examine morphological features of all previously reported members of the family, comparing these with each other and with the new forms in our collections. Despite very noteworthy differences in calyx shape, attitude and relative prominence of the basal plates, outlines of the radial plates with notice of great height-to-width variation in their dimensions and especially of the nature of their articular facets, and range in number of intercalary plates from six to more than 600, all acrocrinids heretofore described have been assigned to the genus Acrocrinus. Moreover, the arrangement of intercalaries, features of the arms, and structures of the tegmen have been overlooked very largely. The possible taxonomic significance of each mentioned morphological distinction has failed to receive attention. Consequently, this paper is the first to offer comparative analyses of the entire assemblage of crinoids assignable to the Acrocrinidae as known to this date. Quite unanticipated at outset of the study has been an expansion of the family to a content of ten genera grouped in two subfamilies. They
take the place of a single all-embracing genus named Acrocrinus. The new classification of these unique Mississippian-Pennsylvanian camerate crinoids reflects the remarkable evolutionary differentiation displayed by them in a short span of late Paleozoic time. In so far as known, the stock did not persist beyond early Late Pennsylvanian.

**SYSTEMATIC PALEONTOLOGY**

**Family ACROCRINIDAE Wachsmuth & Springer, 1885**

[Acrocrinidae Wachsmuth & Springer, 1885, p. 120 (342)]

**DIAGNOSIS.—**Crown ovoid to pyriform, with height exceeding greatest width; arms (where known) erect or pendent, mostly biserial, but may be wholly or in part cuneate uniserial, well rounded externally, pinnulate. Calyx subconical, vaselike, tall ovoid, or subglobular, with two equal basals separated by suture between them oriented anteroposteriorly as in Dichocrinidae; radials five, laterally adjoining one another except C and D radials, which are separated by primanal (X) plate; radials and basalts not in contact but set apart by few to very many intervening supplementary plates collectively designated as intercalaries; tegmen flat to gently convex, with or without differentiated orals and having few or extremely numerous small plates, anal vent near posterior margin, inconspicuous or located at tip of anal pyramid, stem transversely circular, homeomorphic or heteromorphic, with columnal articular facets peripherally crenulate; axial canal diminutive, circular to distinctly pentalobate or stellate in section, with narrow sharp-tipped rays oriented interradially. [The outstanding attribute of this family is the presence of intercalaries in calices of all genera. These may be arranged in moderately regular alternating circlets or appear quite irregular, with proximal plates notably smaller than distal ones. The advent of intercalaries in a late Paleozoic group of camerate crinoids suggests evolutionary reversion to a cystoidlike structure of the calyx and divergence of genera in significant morphological features indicates unusual plasticity of the stock.] Lower Mississippian (Kinderhookian) to Upper Pennsylvanian (Missourian); Upper Lower Carboniferous to Middle Carboniferous.

**DISCUSSION.—**Up to the present time 12 species of crinoids from Mississippian and Pennsylvanian formations of North America have been classed as belonging to Acrocrinus and two additional ones have been reported from Lower and Upper Carboniferous rocks of Europe. These have been reckoned to comprise the entire assemblage included in the family Acrocrinidae or according to Urachs (1953, p. 741) in the subfamily Acrocrininae, placed with so-called Dichocrininae and Talarocrininae in the family Dichocrinidae. The single diagnostic characteristic of Acrocrinus and the Acrocrinidae has been judged to be the presence of circlets of supplemental plates between the two equal basals joined to the transversely circular stem and five subequal radials at the summit of the calyx. The supplemental plates, called intercalaries, are extremely numerous in some species, including A. shumardi, type species of the genus, but comparatively few to very few in others. A critical review of all previously described forms referred to Acrocrinus and study of new ones which we initially thought should be assigned to the genus have called attention to several morphological distinctions which in our opinion warrant division of the old and new species into separate genera. These can be grouped desirably in two subfamilies.

The characteristics which we judge to be significant for generic differentiation include: 1) nature of the radial articular facets, in particular their width, shape, and attitude; 2) upflaring or peripherally upturned basals clearly visible in side views of the calyx, as opposed to their entirely horizontal attitude and invisibility in side views; 3) number and positions of plates in the distalmost circlet of intercalaries; 4) features of the tegmen where determinable, with presence of absence of distinct orals and anal pyramid; and 5) upright or pendent arms. Using these criteria (calyx structure illustrated in Figure 1), the ten genera (nine new) described in this paper can be distinguished. The revised classification of acrocrinids is summarized in the following tabulation.
Fig. 1. Diagrams of acrocrinid plate structure, especially in upper part of calyx (continued on facing page).

[Explanation.—Radials solid black; primanal (X) plate letters A-E for designations of rays in the W. B. Carpenter system (same in all diagrams); distalmost intercalary plates shaded gray, others and bipartite basal circlet unshaded. Not to scale.]

1. Acrocrinus Yandell (based on type species, A. shumardii), characterized by very wide low radials and primanal, articular facets of radials occupying entire distal margin of plate, 18 intercalaries in distalmost circlet with two of these beneath each radial and primanal.
Subfamilies and Genera of Acrocrinidae with
Assignment of Species

Acrocrininae Wachsmuth & Springer, 1885, U.Miss.
(Chesir.)—L.Penn. (Morrow.)
Acrocrinus Yandell, 1885, U.Miss. (Chesir.), L.Carb.
(Visan)
Acrocrinus yandelli Yandell, 1885 (type species),
Up.Chester.
[=Acrocrinus urnaformis Hall, 1858]
Acrocrinus alestokensis Wright, L.Carb. (Visan)
Amphoracrocrinus Moore & Strimple, n. gen., U.Miss.
(Chesir.)
Amphoracrocrinus amphora (Wachsmuth & Springer),
1897 (type species), Low.Chester.
Platyacrocrinus Moore & Strimple, n. gen., L.Penn.
(Morrow.)
Platyacrocrinus brentwoodensis (Moore & Plummer),
1938 (type species), Brentwood Ls.
Planacrocrinus Moore & Strimple, n. gen., L.Penn.
(Morrow.)
Planacrocrinus mixtus Moore & Strimple, n. sp.,
L.Penn. (Morrow.), Brentwood Ls.
Planacrocrinus cubicus Moore & Strimple, n. sp.,
L.Penn. (Morrow.), Brentwood Ls.
Globacrocrininae Moore & Strimple, n. subfam., L.Miss.
(Chesir.)—U.Penn. (type species), Brentwood Ls.
Globacrocrinus Moore & Strimple, n. gen., L.Miss.
(Visan.)—L.Penn. (Desmoines.)
Globacrocrinus primitinus (Moore & Plummer), 1937
(Chesir.)—L.Miss. (Kinderhook.), M.Carb. (Desmoines.)
Globacrocrinus gloriosus Moore & Strimple, n. sp.,
L.Miss. (Desmoines.), Oologah Ls.
Globacrocrinus rotundus Moore & Strimple, n. sp.,
L.Penn. (Morrow.), Wapanucka Ls.

2. Protacrocrinus Moore & Strimple, n. gen. (based on
type species, P. primitius), distinguished by presence
of only six intercalary plates.
3. Amphoracrocrinus Moore & Strimple, n. gen. (based
on type species, A. amphora), resembling Acrocrinus
in wide articular facets of radials, but having single
intercalary beneath each radial and primanal, with total
of 12 intercalaries in distalmost circlet.
4. Platyacrocrinus Moore & Strimple, n. gen. (based on
type species, P. brentwoodensis), radial articular facets
occupying entire distal margin of these plates, 15 inter-
calaries in distalmost circlet.
5. Globacrocrinus Moore & Strimple, n. gen. (based on
type species, G. pilum), with narrow arculate radial
articular facets and eight distalmost intercalaries.
6. Caucacrocrinus Moore & Strimple, n. gen. (based on
type species, C. urnaformis), distinguished by calyx shape
with upsloping basals, radial facets as in Globacro-
crinus, and 11 distalmost intercalaries.
7. Dinacrocrinus Moore & Strimple, n. gen. (based on
type species, D. expansus), basals not visible in side
view of calyx, 12 distalmost intercalaries.
8. Metacrocrinus Moore & Strimple, n. gen. (based on
type species, M. pumilus), lacking D-ray subradial
intercalary, 11 of these plates in distalmost circlet.
9. Planacrocrinus Moore & Strimple, n. gen. (based on
type species, P. mixtus), resembling Caucacrocrinus
in calyx shape and upfurred basals, but with wide radial
articular facets, eight distalmost intercalaries.
10. Springeracrocrinus Moore & Strimple, n. gen. (based
on type species, S. intermedius), lacking any subradial
intercalary in distalmost circlet of these plates, containing
seven in all.

(Missouri.)
Caucacrocrinus urnaformis Moore & Strimple, n. sp.
(type species), U.Penn. (Missouri.), LaSalle Ls.
Caucacrocrinus acutus Moore & Strimple, n. sp.,
U.Penn. (Missouri.), LaSalle Ls.
Dinacrocrinus Moore & Strimple, n. gen., M.Penn.
(Desmoines.)—U.Penn. (Missouri.)
Dinacrocrinus expansus (Strimple), 1951 (type
species), M.Penn. (Desmoines.), Oologah Ls.
Dinacrocrinus elegans (Strimple), 1949, U.Penn.
(Missouri.), Ochelata Gr.
Dinacrocrinus wortheni (Wachsmuth), 1882, U.Penn.
(Missouri.)
Metacrocrinus Moore & Strimple, n. gen., M.Penn.
(Desmoines.)
Metacrocrinus pumilus (Strimple), 1949 (type
species), M.Penn. (Desmoines.), Dornick Hills
Fm.
Protacrocrinus Moore & Strimple, n. gen., L.Miss.
(Kinderhook.)
Protacrocrinus primatius (Laudon & Beane), 1937,
L.Miss. (Kinderhook.), Hampton Fm.
Springeracrocrinus Moore & Strimple, n. gen., L.Miss.
(Visan.)—U.Miss. (Kinderhook.), M.Carb.
Springeracrocrinus intermedius (Springer), 1926 (type
species), U.Miss. (Chester.)
Springeracrocrinus mijatschkowensis (Yakovlev), 1926,
M.Carb. (Moscow.)
Springeracrocrinus praecursor (Springer), 1926,
L.Miss. (Visan.)

The outline just given expresses a taxonomic
diversity of acrocrinids far greater than was an-
ticipated by us when studies of undescribed fossils
from Lower, Middle, and Upper Pennsylvanian
sources in our collections began. It is now evident
that additional materials and thorough investiga-
tions of them are needed to provide understanding of the evolutionary origin of various observed morphologic features, to test the validity of species, genera, and subfamilies within this remarkably plastic assemblage, as well as to distinguish the phylogeny of different lineages. One hardly can doubt that the Acrocrinidae are descendants of dichocrinid ancestors, even though earliest known species of Dichocrinus are little older than Protacrocrinus primitivus and Springeracrocrinus praecursor.

Protacrocrinus is both the oldest and the simplest acrocrinid known. Possibly, but by no means certainly, it is ancestral to all other genera of the family. The correctness of including it in the Acrocrinidae is unquestioned, since all essential morphological features of the calyx—five radials and primanal in the topmost circlet, presence of intercalary plates, and bipartite nature of the basal circlet with suture oriented antero-posteriorly—and the biserial structure of its pinnule-bearing brachial arms are diagnostic characteristics. Little evolutionary change is needed to yield Springeracrocrinus, for this involves only a shift of all distalmost intercalaries to interradial locations and addition of a varying number of intercalary plates between them and the basals. The next most similar acrocrinid, however, is Cauacacrocrinus, with narrowly arcuate radial facets, upflaring basals, and a larger number of distalmost intercalaries. In spite of the fact that this genus is the youngest (Upper Pennsylvanian) of all known representatives of the family, it could be a direct linear derivative of Springeracrocrinus and Protacrocrinus. If true, other members of the Globacrocrininae, all of which (with possible exception of Dinaacrocrinus worteni) occur in Lower or Middle Pennsylvanian formations, would have to be interpreted as side branches of the acrocrinid phylogenetic tree, collectively marked by the horizontal attitude of their basal circlets, invisible in side views of the calyx.

The origin of the Acrocristinae, characterized by very wide radial articular facets and prevalently (if not exclusively) upflaring basals is entirely conjectural. All presently known genera of this subfamily are confined to Upper Mississippian or Lower Pennsylvanian deposits. In Acrocrinus (Chesteran) we find the maximum number of intercalary plates (possibly 600 or 700) and largest number of distalmost intercalaries (18). Pennsylvanian genera display a greatly reduced total complement of intercalaries and distalmost ones ranging from eight to 15. Accordingly, in this group maximum complexity of calyx organization was preceded by comparatively simple structure and was followed by very notable diminution of calyx components. Assuming that all genera here recognized as members of the Acrocrinidae belong together as a natural phyletic group, evolution of different stocks seemingly must be interpreted as embracing an explosive accentuation of "acrocrinid" morphological characteristics developed from an extremely simple initial stage, followed by reversion to relative simplicity of structure. The peak of complexity was attained approximately midway (Late Mississippian) in the life history of the assemblage.

Subfamily ACROCRININAE Wachsmuth & Springer, 1885

[ nom. transl. Urquhart, 1953, p. 741 (ex Acrocrinidae Wachsmuth & Springer, 1885, p. 120)]

Diagnosis.—Calyx tall urn-shaped to medium low bowl-shaped, chiefly characterized by very wide low radials or with these plates moderate in height, all with straight to gently scalloped articular facets occupying entire distal margin; primanal (X) plate in circlet of radials and similar to them in shape or subpentagonal in outline, narrowing upward; basals upflaring, clearly visible from side; intercalaries in few to numerous (2 to 25) well- or ill-defined circlets and ranging in aggregate number from 10 or 15 to as many as 700, distalmost circlet containing 7, 8, 11, 12, 15, or 18 plates, of which seven (including subanals) invariably are located interradially (eight in Acrocrinus) and others radially; tegmen formed by few to extremely numerous plates, with or without differentiated orals, lacking observed anal pyramid. Arms erect or pendent, composed of biserial, pinnule-bearing brachials. Upper Mississippian (Chesteran) to Lower Pennsylvanian (Morrowan), or Upper Lower Carboniferous (Visean).

Description.—Genera and species brought together in this subfamily include much the largest of all known acrocrinids, with height of calyx ranging from 20 to more than 50 mm, and calyx width cf approximately 15 to 30 mm. The highly pinnulate biserial arms of best-preserved specimens may appreciably exceed in their length the total height of the calyx. The arms are unbranched
above bifurcations close to the summit of the calyx, and their number in each ray commonly is four, six, or eight. The Acrocrininae are mostly distinguished from the new subfamily named Globacrocrininae by their exceptionally large number of intercalaries in walls of the calyx, for individuals of Acrocrinus display at least 400 and may have more than 600 such plates. In Amphoracrocrinus intercalaries range in number from about 300 to 500. On the other hand, Platyacrocrinus probably has a maximum of little more than 100 intercalaries. In Planacrocrinus, on the other hand, intercalaries are exceptionally few (commonly only 15 to 40). This genus is included in the Acrocrininae because the shape and width of its radial articular facets are like those of other genera here brought together in the subfamily and its primanal allies it with Platyacrocrinus.

The dimensions of some, but not all species described in this paper, are given compactly by use of the letters D (diameter), H (height), L (length), T (thickness), and W (width), all stated in millimeters.

Genus ACROCRINUS Yandell, 1855

Type Species.—A. shumardi Yandell, 1855; by monotypy.

Diagnosis.—Calyx urn-shaped, with unusually low, wide radials and primanal; distal articular facet of radials supporting minute axillary primibrach 1 and 2 secundibrachs 1, latter followed by axillary secundibrach 2; most distal circlet of intercalaries including 10 small subradials and 8 in interradial positions, those of CD interray comprising 2 small subanals and 2 distinctly larger intercalaries next to them on either side. Arms erect. Stem homeomorphic, composed of very low columnals (Fig. 1,1). Upper Mississippian (Chesteran), North America (USA) and Upper Lower Carboniferous (Visean), Europe (England).

ACROCRINUS SHUMARDI Yandell

Acrocrinus shumardi Yandell, 1855, p. 135, fig.—Wachsmuth & Springer, 1897, p. 806, pl. 80, fig. 1-3.—Springer, 1926, p. 45, pl. 12, fig. 6-7.

Acrocrinus urnaefornis Hall, 1858, p. 690, pl. 25, fig. 9a-b.

Diagnosis.—Characters of genus.

Description.—The height of the elongate calyx (51 mm. in the large holotype specimen) is approximately twice its greatest width, although in the figure given by Wachsmuth & Springer (1897, pl. 80, fig. 1) the width appears to be exaggerated (30 mm.) by flattening. According to R. S. Bassler (personal communication to R. C. Moore), the cited illustration is natural size. It shows excellently the subequal small smooth-surfaced intercalaries, basal circle with indication of the anteroposterior interbasal suture, and 3 radials with proximal parts of attached arms. The rays to which the radials belong are not identifiable beyond observation that none are seen to adjoin the primanal, thus indicating that they could be radials of the A-B-C, D-E-A, or E-A-B rays. The height of the radials (3 mm.) is one-fourth of their width (12 mm.) and height of the basal circle (2.8 mm.) a little more than one-third of its greatest width (7.5 mm.). A diminutive but nearly perfect crown figured by Springer (1926, pl. 12, fig. 6) has a calyx height of 13 mm., calyx width of 9 mm., and height of arms amounting to 29 mm.; part of the attached slender stem has a diameter of 2 mm.

Illustrations.—Fig. 1,1. Diagram showing plate arrangement in summit portion of calyx (broad-faceted radials black, distalmost intercalaries gray) showing 2 subradial intercalary plates in all rays and 2 subanal ones in CD interray, others interradial, 18 in entire circlet.—Fig. 2,1,2. Oblique view of lower part of calyx showing bipartite basal circle beneath irregularly arranged small intercalaries, and lateral view of crown (holotype) with attached proximal part of stem (rays not identified), X2, X1 (both specimens from Glen Dean Limestone in Sloan’s Valley, Pulaski County, Kentucky (Wachsmuth & Springer, 1897).—Fig. 2,3. Side view of small crown (rays not identified), X1.5 (from Glen Dean Limestone at Grayson Springs, Grayson County, Kentucky (Springer, 1926).

Types.—Holotype (location of Yandell’s type not determined). Hypotypes (Fig. 2,1), SI584, U.S. National Museum; (Fig. 2,3) SI583 USNM.

Occurrence.—Upper Chester Group in Breckinridge, Grayson, and Pulaski Counties, Kentucky; Glen Dean Limestone, upper Chesteran, Madison County, Alabama; Paint Creek Formation, middle Chesteran, Pope County, Illinois; all Upper Mississippian.
1-3. *Acrocrinus shumardi* Yandell: 1, oblique view of lower part of calyx clearly showing two equal basals with upflared margins and superjacent small intercalaries not arranged in distinct circlets, ×2; 2, holotype specimen, with most of arms broken away, their bases surrounding large curved-conical shell of capulid gastropod which occupies nearly entire area of the tegmen, ×1; 3, small crown with erect arms and attached portion of stem, ×1.5.

4-8. *Amphoracrocrinus amphora* (Wachsmuth & Springuer), Moore & Strimple, n. comb.; 4, tegmen of specimen, CD interray with anal orifice directed downward,
ACROCRINUS ALVESTONENSIS Wright

*Acrocrinus alvestonensis* Wright, 1958, p. 308, pl. 79, fig. 1-4.

**Diagnosis.**—Very similar to *Acrocrinus shumardi* in all discernible features but only about one-half as large.

**Description.**—Abundant small intercalaries subequal in size throughout most of calyx height, not arranged in well-defined circles; width of calyx (17 mm.) 70 percent of height (24 mm.); height of basal circlet (1.5 mm.) one-third of greatest width (4.5 mm.); stem 4-5 mm. in diameter composed of very low columnals, uniform in appearance throughout proximal portion equal to 3 times height of calyx. Arms round, slender, erect and somewhat outspred, number to ray undetermined.

**Illustration.**—Fig. 2, 9. Holotype, a crushed incomplete crown, ×1.5 (Wright, 1958).

**Discussion.**—This species is based on 3 fairly complete but badly squeezed crowns, 2 with long attached proximal part of the stem. The assignment of the fossils to *Acrocrinus* seems to be well founded and of interest is their approximate equivalence in age to *A. shumardi*.

**Types.**—Holotype, Geological Survey Museum (London), 5091a; paratype, same, 5091b.

**Occurrence.**—Upper Lower Carboniferous (Viscan), S2 Subzone, Gloucestershire, southwest England.

Genus AMPHORACRINUS Moore & Strimple, n. gen.

**Type Species.**—*Acrocrinus amphora* Wachsmuth & Springer, 1897; original designation herein.

**Diagnosis.**—Similar to *Acrocrinus* but differing in its notably taller and narrower radials and primanal, in having only 12 plates in distalmost circlet of intercalaries (five subradial, seven interradial, latter including single subanal), and especially in its robust, long, pendent arms; tegmen formed by extremely numerous small plates without differentiated orals and lacking anal pyramid (Fig. 1, 3). Upper Mississippian (lower Chesteran), USA (Alabama).

×2: 5-6, side views of calices with arm bases, longitudinal furrows marking impressions of pendant arms, ×2; 7-8, crowns with part of long downhanging arms showing closely spaced long pinnules, ×1.5.

AMPHORACRINUS AMPHORA

(Wachsmuth & Springer), Moore & Strimple, n. comb.

*Acrocrinus amphora* Wachsmuth & Springer, 1897, p. 808, pl. 89, fig. 4-9. —Bather, 1900, p. 159. —Springer, 1926, p. 45, pl. 9, fig. 8-9, pl. 12, fig. 8-9, pl. 18, fig. 4.

**Diagnosis.**—Characters of genus.

**Description.**—Calyx somewhat smaller on average than that of *Acrocrinus shumardi* but generally similar in shape, with height typically 1.5 times greater than width. Specimens illustrated by Wachsmuth & Springer have calices ranging in height from 17.5 to 32 mm. and maximum width of 12 to 22 mm. The steeply up-flaring basal circlet of a medium-sized calyx has maximum width of 5.5 mm., minimum width at stem junction of 2 mm. and height of 2 mm. The width of radial plates (av. 3 mm.) is very little greater than their height (av. 2.5 mm.). A very noteworthy attribute of *Amphoracrinus amphora* is its gently arched, many-plated tegmen which lacks differentiated orals and an anal pyramid but shows the anal opening near the CD-interray margin. The very long pendent arms may reach almost as far below the calyx as its full height and the peculiarity of the vertical grooves on sides of the calyx made by their pressure against it is most striking. Diameter of the stem, composed of very low columnals, is normally 2 to 2.5 mm.

**Illustration.**—Fig. 2, 3. Diagram showing plate arrangement in summit portion of calyx (broad-faceted radials black, distalmost intercalaries gray) showing single subradial intercalary beneath each radial and seven others interradial. —Fig. 2, 4-8. Specimens from Monteagle Formation, lower Chesteran, near Huntsville, Madison County, Alabama; all ×2 (Wachsmuth & Springer, 1897); 4, tegmen, showing slightly differentiated plates adjacent to anal opening (lower part of view) but no anal pyramid or differentiated orals, ×2; 5, C-ray view of lectotype (large primanal and longitudinal series of subanal intercalaries near left edge of calyx), ×2; 6, exceptionally tall and slender calyx with arm
bases; 7.8, calices with pendent arms and portion of attached stem, rays not identified.

Discussion.—The most obvious and important differences shown by Amphoracrinites amphora as compared to Acrocrinus shumardi are its proportionally much taller and nearly quadrate radials, its smaller number of distalmost intercalaries, with only a single such plate beneath each radial, and the pendent nature of its arms. No other acrocrinid genus and species with multiple articular facets occupying the entire distal margin of the radials possesses such relatively tall plates in this circlet, and none of these matches A. amphora in having one intercalary plate next beneath every radial. Finally, this species is unique in the pendent attitude of its arms.

Types.—Lectotype, U. S. National Museum, no. S1577 (specimen illustrated by Wachsmuth & Springer, 1897, pl. 80, fig. 6), herein designated, shown in this paper as Fig. 25; other specimens here illustrated (also USNM no. S1577) designated as paralectotypes.

Occurrence.—Monteagle Formation (Gasperean), lower Chesteran, near Huntsville, Madison County, Alabama.

Genus PLATYACROCRINUS Moore & Strimple, n. gen.

Type Species.—Acrocrinus brentwoodensis Moore & Plummer, 1937 (1938), p. 222; original designation herein.

Diagnosis.—Radials most similar to those of Acrocrinus in being very low and wide; primanal distinctive in its subpentagonal shape, narrower than radials, with distal tip projecting slightly above rim of calyx; intercalaries fewer and relatively larger than in other genera of subfamily, most distal circlet containing 15 plates, of which eight are subradial (single ones beneath C and D radials, pairs of plates beneath other radials) and seven interradial in position, with 3 plates in CD interray (including subanal); tegmen, lower part of calyx (Fig. 4A). Arms and stem unknown. Lower Pennsylvanian (Morrowan), USA (NW. Arkansas-NE. Oklahoma).

PLATYACROCRINUS BRENWOODENSIS (Moore & Plummer), Moore & Strimple, n. comb.

Acrocrinus brentwoodensis Moore & Plummer, 1937 (1938), p. 222, pl. 12, fig. 5a-d, text-fig. 3.

Diagnosis.—Characters of genus.

Description.—Only the radial circle and primanal with subjacent 2 circles of intercalaries are preserved in the holotype (Fig. 3,1-4). These are quite sufficient, however, to set the species apart from other known acrocrinids. The top part of the calyx is nearly vertical-sided, gently rounded in longitudinal profile, with slight inward slope to summit of the radials. It is 15 mm. in diameter and the incomplete fossil measures 10 mm. in height. Width across the calyx between inner edges of the radials is 10 mm. The radials, with average greatest height of 2.0 mm. and width of 7.0 mm., have almost exactly the proportions of corresponding plates in Acrocrinus shumardi (ratio of height to width 28.5 percent in this species and 25 percent in A. shumardi). Articular facets of the radials, which reach laterally to the interradial sutures, are almost imperceptibly concave in lateral profile and subhorizontal from outer to inner margins, with average length of 2.5 mm. along this short axis of the facets. They are most similar to the radial facets of Planacrocrinus Moore & Strimple, n. gen., in displaying a narrow but faint transverse ridge, shallow muscle fields and wide, rather indistinct intermuscular notch. The primanal of Platyacrocrinus brentwoodensis is distinctive in its distally rounded or pointed pentagonal outline, with tip rising slightly above the level of the radial facets. Subanal intercalaries occur directly beneath it. Other distalmost intercalaries include 6 in interradial position and 8 centrally placed beneath radials. The interradial intercalaries are 1.9 to 4 mm. in height and width; the height and width of subradial intercalaries is 2.8 to 3.0 mm.

Another specimen (USNM 33067), only half as large as the holotype or a little smaller, is a complete calyx with well-defined sutures between nearly all of the plates (Fig. 4). It is vertically compressed and deformed by obliquely directed pressure which has tended to flatten the B-E sides of the calyx. Measurements of greatest diameters (6.5 to 8.5 mm.) and height (6 to 8 mm.) furnish basis for estimating that width and height of the undeformed subglobular calyx to have been approximately 7 mm. The margins of the basal circlet, 2.7 mm. in diameter, slope outward and upward, being visible in side view of the calyx. Near the level of the distalmost intercalaries the calyx sides curve rather abruptly and slope inward to the summit of the radials. The width of the radials is 3 to 4 times their height (A radial 3.8...
Moore, Strimple—Mississippian-Pennsylvanian Camerate Crinoids

mm. wide, 1.0 mm. high; D radial 2.6 mm. wide, 0.9 mm. high). The articular facets of these plates bear straight transverse ridges reaching nearly or entirely to the interradial sutures; they are very narrow and sharp-crested. Bordering them on the outer side is a shallow ligament fossa and on the inner side are ill-defined muscle areas separated by a shallow to somewhat narrow inter-

Fig. 3. Platycrinus and Globocrinus Moore & Strimple, n. gen.


5-10. Globocrinus pirum (Moore & Plummer). Moore & Strimple, n. comb.; views of calices, all X3.—
Fig. 4. *Platyacrinus brentwoodensis* (Moore & Plummer), Moore & Strimple, n. comb. (continued on facing page).
muscular notch. The attitude of the facets is subhorizontal. The primanal is relatively shorter than in the holotype and has a subhexagonal outline with rounded distal extremity; it is approximately the same in width and height (2.0 mm.) as the interradial intercalaries and very little larger than the subanal intercalary. The intercalaries are arranged in seven or eight ill-defined circlets with

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**Fig. 5. Platyacrocirinus brentwoodensis (Moore & Plummer), Moore & Strimple, n. comb.**

1-4. Camera lucida drawings of nearly complete, undeformed calyx (SUI 33445) from northeastern Oklahoma, all ×4.5: side views of CD interray, C, B, and A rays.

FIG. 6. Planacrocinus ambix Moore & Strimple, n. gen., n. sp. (continued on facing page).
regularly diminished size of the plates toward the base. The aggregate number of these plates is not less than 100 and may be somewhat more.

A nearly complete undeformed calyx (SUI 33445), also collected from the Brentwood Limestone of northeastern Oklahoma, is subglobular in shape, somewhat abraded at the top and broken at the base, but showing very well most of the calyx sides (Fig. 5). The intercalaries are regularly hexagonal and diminish only moderately in size downward. The basal circllet and most proximal intercalaries are missing. Outer surfaces of the intercalaries are very gently convex and marked by irregular slight vermiciform ridges. Sutures between the intercalaries are distinct and faintly depressed. The calyx is vex and marked by irregular slight vermiform ridges. Sutures between the surfaces of the plates and may be somewhat more.

ILLUSTRATIONS.—Fig. 1,4. Diagram showing radial circllet and primanal with subjacent 15 intercalaries bilaterally symmetrical in arrangement with respect to ACD axis (based on holotype.—Fig. 3,1,4. B-ray, CD-interray, A-ray, and ventral views of holotype, x2, from Brentwood Limestone (Bloyd Formation), Morrowan, near Woolsey, Washington County, Arkansas (Moore & Plummer, 1938).—Fig. 4,1-8. Camera lucida drawings of complete but deformed hypotype (SUI 33067) from vicinity of Choteau (NE SW sec. 1, T. 20 N., R. 18 E.), Mayes County, Oklahoma, all x8; 1, A-ray side of calyx; 2, AB-interray view; 3-6, oblique views of post. side of calyx from above; 7, E-ray view; 8, oblique view of dorsal side of calyx.—Fig. 5,1-4. Camera lucida drawings of specimen SUI 33445 in side views directed toward CD interray, C, B, and A rays, x4.5 (broken lines indicating restoration).

1-8. Camera lucida drawings of holotype specimen, all x10 (except 8, which is x22).—1-2. Ventral view showing broad-faced radial-plate circllet and narrow distal edge of primanal (above) surrounding open tegmental space with remnants of poorly preserved subhorizontal orals, and dorsal view showing equal basalts and adjacent proximal intercalaries in fairly regular circllets (primanal plate at top), stem impression with fine short peripheral crenulate and pentalobate lumen, its projections directed interradially.—3-7. Side views of calyx showing even horizontal summit, upflared basalts, and circllets of intercalary plates, seen from A, B-, D-, and E-ray sides and CD-interray side.—8. Articular facet of A radial with narrow, straight transverse ridge crossing widest part of facet and separating broad, shallow outer ligament area from nearly flat inner ligament and muscle areas, two minute nerve canal openings near tip of intermuscular notch.

**Genus PLANACROCRINUS Moore & Strimple, n. gen.**

**Type Species.—**Planacrocrinus ambix Moore & Strimple, n. sp.

**Diagnosis.—**Calyx flat at base and summit, bowl-shaped to subcomical with steep nearly straight sides, basals clearly visible in side view; radials wider than high, with straight articular facets occupying full width of plates and extending well inward from outer margin, resembling facets of such inadequately crinoids as Delocrinus and Cromyocrinus in presence of ligament fossae, transverse ridge, muscle-attachment areas, and intermuscular notch; and D radials separated by hexagonal primanal which is widest in lower third and narrowest at summit slightly below level of radical facets or even with them; circllet of distalmost intercalaries composed of eight plates, only A radial having one directly beneath it (Fig. 1,9); tegmen and arms unknown. Lower Pennsylvanian (Morrowan).

**PLANACROCRINUS AMBIX Moore & Strimple, n. sp.**

**Diagnosis.—**Characters of genus.

**Description.—**The calyx of this species is bowl-shaped, with height subequal to width or distinctly less than greatest width. Upward sloping sides of the lower part of the calyx curve evenly to a vertical attitude at the summit, or in this part they may turn very slightly inward. The
FIG. 7. Planacrocinus ambix Moore & Strimple, n. gen., n. sp. (continued on facing page).
flat base, with well-marked stem impression, is one-third as wide as the calyx summit, which corresponds to it in being evenly horizontal. Peripheral parts of the basals slope upward and therefore are easily visible in side view, height of the circlet amounting to approximately 0.1 that of the calyx. The radials are distinctly wider than high; all have pentagonal outlines except the A radial, which is hexagonal. Their horizontal articular facets are approximately one-half as long measured normal to the transverse ridge, as wide, measured along this ridge. Outside the transverse ridge, extending nearly to the radial margin, is a shallow but distinct ligament fossa and inside are broad muscle areas with ill-defined surface features. The two muscle fields of each facet are separated by a deep, comparatively narrow intermuscular notch, at the base of which on some facets two tiny openings for nerve canals are discernible.

The primanal (X) plate is hexagonal in outline, with greatest width slightly below midheight, this width being equal to total height. Proximal and distal margins of the plate are subequall, the latter not quite reaching to the summit of the adjoining C and D radials. Directly beneath the primanal are subanal intercalaries, two in small juvenile specimens or three in the holotype, judged to represent an adult. Similarly, two or three subradial intercalaries underlie the hexagonally shaped A radial. Distalmost intercalaries additional to the subanal and subradial ones mentioned are all interradial in position. They are comparatively large and all are hexagonal in shape. The total number of intercalaries ranges from approximately 18 in small juveniles to about 40 in adult specimens.

Paired basals, as throughout the family, are separated by an anteroposteriorly directed suture. The peripheral parts of these plates slope gently upward in confluence with curved sides of the calyx and are plainly visible in side views. The stem impression and proximal columnnals have diameter of one-half that of the basal circllet or a little less. A narrow band of short, moderately strong crenulae surrounds a broad, smooth areola.

The axial canal and lumen are distinctly stellate in transverse section, with round-tipped extremities of the rays directed interradially.

The tegmen of Planacrocrinus ambix is unknown, except for the observation of five poorly preserved orals partly displaced from their interradial positions into a central group of the summit of the holotype (Fig. 6,1). One of the paratypes, a small juvenile specimen, retains a single stout tegminal plate which rises steeply upward and inward from the DE interradial suture (Fig. 7,1). It corresponds to the DE suboral of P. minutus, suggesting that the tegmen of P. ambix also was characterized by the presence of a rounded pyramid of oral and suboral plates.

Dimensions (in millimeters) of the holotype and paratype, the latter enclosed by parentheses, are as follows. Calyx: H, 5.0 (2.2); D at summit, 5.3 (3.0); D at base (less than that of basal circllet), 1.7 (0.9). A radial: H at mid-line, 1.5 (1.1); H at interradial sutures, 1.0 (0.7); W, 2.8 (1.6); L of articular facet from outer to inner margin, 1.5 (0.9). Primanal (X) plate: H, 1.9 (1.3); maximum W, 1.9 (1.3). Basal circllet: H, 0.5 (0.5); D, 3.2 (1.5); stem impression, D, 0.6 (0.6).

Illustrations.—Fig. 1,9. Diagram showing plate arrangement in summit portion of calyx (radials with wide, straight articular facets black, distalmost intercalaries gray), subradial intercalary only in A ray.—Fig. 6,1-8. Camera lucida drawings of holotype (SUI 33105), all ×10 (except 8, which is ×22); 1-2, ventral and dorsal views; 3-7, A, B, D, E-ray, and CD-interray views; 8, radial articular facet, ×22. —Fig. 7,1-8. Camera lucida drawings of paratype (SUI 33106), all ×18; 1-2, ventral and dorsal views, former showing suboral plate in DE interray; 3-8, A, B, C, D, E-ray and CD-interray views (profile of suboral shown in 4, 7, and 8). Types.—Holotype, SUI 33105; paratype, SUI 33106. Collected by Allen Graffham.

Occurrence.—Wapanucka Limestone, Lower Pennsylvanian (Morrowan), Canyon Creek near Pittstown, Pontotoc County, Oklahoma.

1-8. Camera lucida drawings of small paratype specimen, all ×18. —1-2. Ventral view (distal extremity of primanal at top) showing single preserved suboral plate projecting strongly upward from DE interradial suture, and dorsal view showing basals with greatest width in direction normal to interbasal suture and illustrating relatively small number of intercalaries arranged in two circllets. —3-8. Side views of calyx looking toward A, B, C, D, and E rays and CD interray (profile of suboral shown in 4, 7, and 8).
**PLANACROCRINUS CONICUS** Moore & Strimple, n. sp.

*Diagnosis.*—Similar to *Planacrocrinus ambix* in all essential structural features of calyx, but distinguished by its much greater height in relation to width and its nearly straight, very steeply sloping sides.

*Description.*—The calyx has the form of a tall truncate cone with summit diameter slightly greater than twice that of the base, the former equaling 75 percent and the latter 60 percent of total calyx height (Fig. 8). Most of the basal circlet is disposed horizontally but its peripheral parts slope steeply upward in line with higher sides of the calyx. The radials correspond in general features to those of *Planacrocrinus ambix*, but the primanal is proportionally taller and much narrower at the summit than in that species, with the tip even or slightly above the C and D radial articular facets (Fig. 8.5). The intercalaries are as numerous as in adult specimens of *P. ambix*, and like them, show distinct diminution in size toward the basal circlet.

The radial articular facets, disposed in a common horizontal plane, have well-defined narrow transverse ridges, shallow outer ligament fossae, and well-marked muscle areas separated by a shallow intermuscular notch. No parts of the tegmen are preserved.

Dimensions (in millimeters) of the calyx and some of its component parts are as follows. Calyx: D summit, 2.8; D at base (less than that of the basal circlet), 1.6; H, 5.2. A radial: H at midline, 1.2; H at interradial sutures, 0.8; W, 1.6; L of articular facet, 0.8. Primanal (X) plate: H, 1.8; maximum W, 1.5. Basal circlet: D, 2.0; H, 0.9; stem impression, D, 0.8.

*Illustrations.*—Fig. 8,1-5. Camera lucida drawings of the holotype (SUI 33107); 1-3, A-, B-, and D-ray views of calyx, X10; 4-5, CD-interray and ventral views of calyx, latter with A ray central below, X22.

*Discussion.*—Diminutive size and very steep straight sides are obvious distinguishing features of this species. The holotype is judged to be an adult individual for it has a somewhat larger complement of intercalary plates than adult *Planacrocrinus ambix*. Four subanal and four subradial intercalaries in the A ray are observed instead of the three of *P. ambix*.

*Type.*—Holotype SUI 33107 (only known representative of the species). Collected by R. C. Moore.

*Occurrence.*—Brentwood Limestone (Bloyd Formation), Lower Pennsylvanian (Morrowan), at Greenleaf Lake, north of Muskogee, Oklahoma.

**PLANACROCRINUS MINUTUS** Moore & Strimple, n. sp.

*Diagnosis.*—Calyx proportionally taller than in *Planacrocrinus ambix* and with far fewer plates as well as steeply upflaring borders of basal circlet notably taller; tegmen marked by prominent oral pyramid composed of oral plates at summit, supported by suborals which rise from interradial sutures. Arms and stem unknown.

*Description.*—This species is based on a single complete calyx which is slightly compressed anteroposteriorly. It is notably smaller than *Planacrocrinus ambix* and *P. conicus*, with profile in side view intermediate between these two species (Fig. 9.2-10). Diameter of the radial circlet is nearly half of the calyx height and the basal circlet one-fourth of it, leaving room between them for only a double row of intercalaries, large ones located distally and small ones proximally. The primanal (X) is a lozenge-shaped plate with greatest width slightly below mid-height. Its summit, slightly below the level of the radial facets, is distinctly narrower than the base. It is underlain by a single subanal intercalary plate, instead of the two circlets of intercalaries beneath radials.

The oral pyramid has steeply sloping sides and pointed to rounded summit (Fig. 9.2-10). The lower half of its height is composed of five suboral plates and the upper part by five closely adjoined orals, the posterior one of which is slightly larger than others. The base of the oral arch, formed by...
proximal extremities of the suborals, is well inside the outer edges of the horizontal radial articular facets. These have narrow straight transverse ridges and on the inner side shallow intermuscular notches.

Dimensions of the holotype (in mm.) are as follows. Calyx: H, 2.3; D (summit), 2.0 and 2.6, mean 2.3; D (base), 1.0 and 1.4, mean 1.2. B basal circlet: H, 0.5; D (stem impression), 0.6. Oral pyramid; H, 1.1; W (at base), 1.5. A radial; H (mid-line), 0.9; H (at interradial suture), 0.7; W (summit), 1.7; W (base), 0.7. Primanal (X) plate: H, 1.2; W, 1.0.

Illustrations.—Fig. 9,1-10. Camera lucida drawings of holotype (SUI 32482), only known specimen, all ×18; I-2, ventral and dorsal views of calyx, former showing centrally grouped orals and supporting suborals; 3-10, A-, AB-, B-, C-, CD-, oblique D-, D-, and E-ray and interray views.

Type.—Holotype, SUI 32482. Collected by Allen Graffham.

Occurrence.—Brentwood Limestone (Bloyd Formation), at Greenleaf Lake, north of Muskogee, Oklahoma.

Subfamily GLOBACROCRININAE

Moore & Strimple, n. subfam.

Distinguished from Acrocrininae by narrow, moderately to strongly arcuate radial articular facets; basals visible or not visible from side; distalmost ring of intercalaries composed of six to 12 plates, of which seven are located interradially in all but one genus (Protacrocrinus), subradial intercalaries ranging from none to five, some genera with longitudinal series of superposed intercalaries beneath one to three radials in addition to primanal series present in all; tegmen with distinct orals recognized in some genera, posterior one largest, and commonly showing low anal pyramid near CD border. Upper Mississippian (Chesterian)-Upper Pennsylvanian (Missourian), Middle Carboniferous (Moscovian).

Description.—Chief characteristics of species grouped in the Globacrocrininae are found in the generally diminutive to very small size of the calyx and greatly reduced number of intercalaries in comparison to the Acrocrininae. Maximum calyx height in any species is only 18 mm., and calyx width 15 mm. From these measurements height and width of the calyx ranges down to 5 mm. The number of intercalaries is largest in some species of Globacrocrinus (approximately 175), which is barely one-third or less of the intercalary plates in calices of Amphoracrocrinus and Acrocrinus. The narrow and more or less strongly arcuate facets at the summits of radial plates is another diagnostic feature of this subfamily. In stratigraphic span and in being represented on both sides of the Atlantic, the Globacrocrininae match distribution of the family.

Genus GLOBACROCRINUS Moore & Strimple, n. gen.

Type Species.—Acrocrinus pirum Moore & Plummer, 1937 (1938), p. 218; original designation herein.

Diagnosis.—Calyx pear-shaped to globose, basals not visible from side; small to very diminutive radials with height and width subequal, little larger than distalmost intercalaries, which form circle of 8 plates with subradial one confined to A ray, others (including subanal) interradial in position, longitudinal series of intercalaries beneath A radial and primanal; tegmen with orals and anal pyramid. Stem slightly heteromorphic, at least next to calyx. Arms unknown. Lower Pennsylvanian (Morrowan) to Middle Pennsylvanian (Desmoinesian).

Description.—This genus is the most robust in size of the calyx and largest in number of intercalaries of any unit included in the subfamily. Average height of calyx in different species ranges from 7.5 to 18 mm., and width from 6 to 15 mm.; for the whole genus these dimensions have means of 10 and 9 mm., respectively. The horizontal basals may be flush with the evenly rounded, essentially flat bottom part of the calyx or located in a shallow depression. In most specimens of Globacrocrinus, the tegmen is not preserved, but in some forms 5 prominent, subhorizontally dis-

1-10. Camera lucida drawings of holotype calyx, all ×18.
I-2. Ventral and dorsal views, former showing exceptionally broad flat articular facets of radials surmounted by arch of five suboral and five oral plates (posterior oral largest and oriented upward).—3-10. Side views of calyx looking toward A ray, AB interray, B and C rays, CD interray (hexagonal primanal facing viewer), two D and E ray sides, all showing strongly elevated oral-suboral arch (only profile of it in 8).
posed orals are seen, the posterior one trapezoidal in outline and double the size of others. Also, a very low anal pyramid may be present just above and inside the primanal. The nature of arms and stem in *Globacrocrinus* is unknown.

**DISCUSSION.**—Compared with other genera of the subfamily, *Globacrocrinus* is not only distinguished by characteristics mentioned in the preceding description but by the number and arrangement of its distalmost intercalaries. Only one of these plates occurs directly beneath a radial (*A* ray) in *Globacrocrinus*, whereas *Proacrocrinus* and *Dinacrocrinus* have 5 such plates, *Metacrocrinus* 4, and *Springeracrocrinus* none. The most distal circlet of intercalaries consists of 12 plates in *Dinacrocrinus*, 11 in *Metacrocrinus*, 8 in *Globacrocrinus*, and only 7 in *Springeracrocrinus*.

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**Fig. 10.** *Globacrocrinus glosus* Moore & Strimple, n. gen., n. sp.

1-4. Camera lucida drawings of holotype calyx, all X10.

1-2. Side views looking toward CD and AB interrays showing subquadrate outline of calyx with broadly truncate, slightly hollowed base and nearly flat summit.

3-4. Dorsal and ventral views, basals not preserved; five orals at summit sloping upward very gently toward center, large posterior oral oriented toward top.
GLOBACROCRINUS PIRUM (Moore & Plummer), Moore & Strimple, n. comb.

_Eacrocrinus pirum_ Moore & Plummer, 1937 (1938), p. 218, fig. 1, 2g, pl. 12, fig. 1a-d.

**Diagnosis.**—Calyx small, pear-shaped, with greatest diameter at about one-third of height above flat to slightly concave base, sides sloping steeply and evenly upward-inward toward summit; plates smooth, not convex, their surface evenly confluent with adjoining plates so as to produce regular contour of calyx sides and base; sutures between plates distinct but not impressed, their

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_Fig. 11. Globacrocrinus rotundus_ Moore & Strimple, n. gen., n. sp.


1-2. Ventral view showing broadly arcuate radial articular facets slightly less than equal to distal width of radials (primanal directed toward top), and dorsal side of calyx, basal relatively small.—3-4. Side views looking toward _D_ and _E_ rays, outline of calyx rounded pear-shaped, intercalaries of sides moderately large and nearly even, in contrast to small plates of calyx bottom.
components and arrangement in accordance with characters of genus.

DESCRIPTION.—The nearly straight sides of the calyx converge toward the relatively narrow summit. The height and greatest width of the holotype are 18 and 15.5 mm., respectively, and in a paratype 14.5 and 11.5 mm. Across the summit of the radial circle, diameter of the calyx is approximately 7 mm. (holotype somewhat deformed in this part) and 5.5 mm. (small but undeformed paratype). The diminutive basal circle is 2.5 mm. in both specimens. The hexagonal primanal is readily distinguished from all radials by its even distal margin and lack of an arcuate facet.

![Diagram of calyx](image)

**FIG. 12.** *Globacrinites rotundus* Moore & Strimple, n. gen., n. sp.

It is approximately equal to the radials and distal-most intercalaries in size, and like the radials, is wider than high. The intercalary plates are arranged in nine or ten ill-defined rows girdling the calyx and by count number 160 to 170, including the irregular small plates surrounding the paired basals. The basal circle is 2.5 mm. in diameter.

Illustrations.—Fig. 15. Diagram showing plate arrangement of calyx (radials black, distal-most intercalaries gray) (Moore & Plummer, 1938, mod.).—Fig. 3-10. Views of calices, all X3; 5-7, ventral, CD-interray, and dorsal views of paratype; 8-10, ventral, CD-interray, and C-ray views of holotype (Moore & Plummer, 1938).

Discussion.—This species resembles *Globacrocrinus rotundus* but is two or three times larger and has straighter upper sides of the calyx which converge more strongly toward the summit. Also, its intercalary plates are distinctly greater in number.

Types.—Holotype, KU45192, from loc. 4519; paratype, KU45212, from loc. 4521; both repositioned on indefinite loan in U. S. Natl. Museum.

Occurrence.—Brentwood Limestone (Bloyd Formation), Lower Pennsylvanian (Morrowan), northeastern Oklahoma. Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Muskogee County; holotype collected by C. L. Foster. Loc. 4521, on...
Fig. 15. *Globacrocinus rotundus* Moore & Strimple, n. gen., n. sp. (continued on facing page).
Braggs Mountain, about 3 miles southeast of Fort Gibson; paratype collected by R. C. Moore.

**GLOBACROCRINUS GLOMUS** Moore & Strimple, n. sp.

**Diagnosis.**—Differs from *Globacrocirinus pirum* in globose shape of calyx, smaller size, and fewer intercalaries.

**Description.**—The holotype, which is the only yet-collected specimen, is a slightly deformed calyx with steep gently rounded sides and truncate base and summit. It is complete, except for the missing basals and a few adjoining small intercalaries. The base is almost imperceptibly concave. Height and greatest width of the calyx are subequal, amounting to 6.5 mm. Width measured at the proximal margin of the radial circlet is 5.5 mm. and at its distal margin 4.5 mm. Height and width of individual radials and of the primanal are 1.5 and 2.5 mm., respectively. Space at the summit of the calyx between the radials is nearly filled by five subhorizontal oral plates, the posterior one 1.9 mm. wide at its straight primanal-facing base and 1.7 mm. in height. The other oral plates are 1.2 mm. in height and 0.9 mm. in greatest width. Intercalaries in series beneath the A radial and primanal number 7 or 8. As in *Globacrocirinus pirum*, intercalaries are not arranged in well-defined circlets.

**Illustrations.**—Fig. 10,1-4. Camera lucida drawings of calyx (holotype) in CD- and AB-interray, basal, and summit views, ×10.

**Discussion.**—The contour of the calyx of *Globacrocirinus glomus*, especially its rounded quadrat outline in side view, with relatively wide flat base and truncate summit, most closely resembles *Dinacrocirinus expansus* (Strimple) and *D. wortheni* (Wachsmuth), but these crinoids are readily distinguished by their 12 distalmost intercalary plates, four more than in *Globacrocirinus*, and of course a different arrangement of these plates. Specimens of *G. rotundus* are more rounded at base of the calyx and are narrower at the summit.

**Type.**—Holotype, SUI 32931. Collected by H. L. Strimple.

1-6. Camera lucida drawings of paratype (SUI 32939) with unusually even-sized intercalaries in fairly well-defined circlets, all ×17; seen from base of calyx (CD interray above), from CD-interray, A- and B-ray, DE-interray, and ventral sides (primanal above).

**GLOBACROCRINUS ROTUNDUS** Moore & Strimple, n. sp.

**Diagnosis.**—Essentially with morphological features of *Globacrocirinus glomus* but lower part of calyx very evenly rounded, instead of concavely truncate, upper part also well rounded or with nearly straight sides converging inward to narrow radial circlet; radial articular facets proportionally wider and shallower than in *G. glomus*.

**Description.**—This species is based on five perfect calices which range in height from 3.9 to 7.8 mm. and in greatest width from 4.0 to 7.5 mm.; average height for all specimens is 5.4 mm. and greatest width 5.3 mm. Width at the proximal margin of the radial-primanal circlet averages 4.9 mm. and at the distal edge 3.5 mm. The aggregate number of intercalaries ranges from approximately 70 in small specimens to 120 or more in large ones. Diameter of the basal circlet in the moderately large holotype is 2.0 mm. and that of the stem impression 1.0 mm. In this specimen average height and width of radial plates are 2.3 and 2.7 mm., respectively. No attached proximal columnals of the stem are seen and none of the calices is associated with arms, although one paratype (OU 6643) has stout primibrachs just inside the arcuate radial facets. Some of these brachials show very fine short crenulae along their convex outward-facing edges. Oral plates are not found at the summit of any specimen, although doubtless they once were present.

**Illustrations.**—Fig. 11,1-4. Camera lucida drawings of holotype in ventral (CD interray above), dorsal (also CD interray above), D- and E-ray views, all ×9.—Fig. 12,1-4. Camera lucida drawings of holotype (OU 6440) in A-, B-, C-ray and CD-interray views, all ×9.—Fig. 13,1-7. Camera lucida drawings of paratype (OU 6441) in A-, B-, C-, D-, E-ray, CD-interray, and ventral views (CD interray above), all ×9.—Fig. 14,1-2. Camera lucida drawings of paratype (OU 6443) in A-ray and ventral views, ×7.5.—Fig. 15,1-6. Camera lucida drawings of paratype (SUI...
32939) with unusually even-sized intercalaries in upper part of calyx, in dorsal (CD interray above), CD-interray, A-, B-ray, DE-interray, and ventral (CD interray above) views, all ×17.

**Discussion.**—At least three of the paratypes of *Globacrocrinus rotundus* are small specimens, with mean height of the calyx measured as 4.2 mm. and mean width as 4.4 mm. These are judged to be juvenile forms, not only because of their diminutive size but because they possess only half as many intercalaries (approximately 40) as seen in the holotype and a nearly as large paratype, which have 80 to 85 intercalary plates. The main distinguishing characteristic of the species is the globose form of the calyx. The holotype is slightly pear-shaped, with gently curved upper sides which slope inward to the relatively narrow summit. Although this suggests *G. pirum*, the calyx of *G. rotundus* is proportionally wider and lower. Also, the paratype specimens are sub-spherical in shape.

**Types.**—Holotype (OU 6440), paratypes (OU 6441-6443, SUI 32939), all from Wapanucka Limestone near Fittstown, Oklahoma. Collected by Allen Graffham (except SUI 32939 by R. Alexander).

**Occurrence.**—Wapanucka Limestone, Lower Pennsylvanian (Morrowan), Canyon Creek near Fittstown, Pontotoc County, Oklahoma.

**Genus CAUCACROCRINUS Moore & Strimple, n. gen.**

**Type Species.**—Caucacrocrinus urnula Moore & Strimple, n. sp.

**Diagnosis.**—Diminutive calyx urn-shaped or lanceolate in outline, pointed at base, basals distinctly upflaring, visible from side; distalmost intercalaries normally forming circle of 11 plates, with subradial ones directly beneath A, C, D, and E radials or exceptionally with subradials in all rays; tegmen with low to moderately prominent anal pyramid at its posterior margin adjoining primanal (X) plate, and accompanying this on its anterior side five subhorizontally disposed orals at level of the radial articular facets, posterior oral distinctly larger than others; remainder of tegmen covered by minute plates; only known parts of arms consist of primibrachs which have deep ambulacral embayment on inner side, are strongly rounded externally, and have distal articular facets parallel to proximal ones, thus indicating uniserial proximal arm structure, as in other acrocrinids. Stem transversely circular, and heteromorphic (at least in proximal part attached to calyx); columnar articular facets with moderately course short crenulae, with small transversely stellate axial canal, rays of which are directed interradially. *Upper Pennsylvanian (Missourian).*

**CAUCACROCRINUS URNULA** Moore & Strimple, n. sp.

**Diagnosis.**—Characters of genus.

**Description.**—Upper walls of the calyx are vertical or curved very slightly inward, whereas well-curved lower ones converge to meet the small basal circlet confluently (Fig. 16). Peripheral parts of the basals slope steeply upward and thus are clearly visible in side views of the calyx. The height and maximum width of radial plates are subequal or width slightly exceeds height. Most of these plates and the primanal (X) are hexagonal in outline but in some specimens the B radial is pentagonal. Approximately one third of the summit of the radials is occupied by a strongly arcuate articular facet, with shoulders on either side sloping gently to the interradial sutures. Distalmost intercalary plates are distinctly, but not greatly, smaller than the radials and primanal; lower ones decrease regularly in size toward the base. The aggregate number of these plates in the holotype and similar adult specimens exceeds 100, whereas in small juvenile individuals the number is only half as great. Intercalaries of the A ray and some others are arranged in longitudinal series, as are subanal ones. Most are hexagonal but some are pentagonal or heptagonal. A relatively prominent anal pyramid covered by small irregular polygonal plates is located next to the primanal plate on the posterior margin of the tegmen (Fig. 16, I-6; 17, I-7; 18, I-3). The summit is rounded and the sides slope steeply. Just in front of its base is a large subtrapezoidal posterior oral plate and near it in interradial positions are four smaller orals, all of these plates having flat smooth upper surfaces.

A few proximal columnals attached to the holotype and some paratypes display a moderately distinct heteromorphic succession, taller stem elements displaying a longitudinally convex profile and smooth sides. Around the margins of columnal articular facets are short evenly spaced
1-5. Camera lucida drawings of holotype specimen (IGS 42P87), side views of calyx looking toward AB inter-ray, B ray, CD inter-ray, D and E rays, all showing upflared basals, first primibrachs attached to narrowly arcuate radial articular facets, and prominent anal pyramid, all X13.5.

6-7. Similar views of calyx summit and base, former showing three subhorizontally disposed oral plates, posterior one largest and juxtaposed to anterior lower edge of anal pyramid, both X13.5.
crenulae. The small axial canal is transversely stellate in outline, with rays directed interradially.

Dimensions (in mm.) of the holotype (Fig. 16) and a juvenile paratype (IGS 42P88) (Fig. 17), the latter enclosed by parentheses are as follows. Calyx: H, 4.50 (2.60); W (maximum, at or near summit), 3.50 (2.20). A radial: H (midline), 1.00 (0.80); H (at interradial suture), 0.77

Fig. 17. *Cucracrinus wunla* Moore & Strimple, n. gen., n. sp.

1-6. Camera lucida drawings of juvenile specimen (paratype IGS 42P88) with attached proximal columnals, side views of calyx showing upflared periphery of basal circket, first primibrachs in some rays, and relatively prominent anal pyramid with largest plate next to primanal, looking toward A, B, C, and D rays, and CD and DE interrays, all ×17 (apparent variation in calyx width due to moderate lateral distortion).

7-8. Similar views of calyx summit and base, former showing five orals in front of anal pyramid, posterior oral largest (CD interray in upper position in both views), ×17.
(0.55); W, 1.70 (1.00); W (articular facet), 0.59 (0.44). Subradial and subanal intercalary (same): H, 1.00 (0.63); W, 1.10 (0.70). Basal circlet: H, 0.44 (0.30); W, 1.20 (0.93); stem impression, D, 0.67 (0.63). Anal pyramid: H, 1.00 (0.59); W, 1.50 (1.00).

Two paratypes of Caecacrocrinus urnula call for special notice because they reveal features of the arms and stem. Both are somewhat compressed laterally and both are partly embedded in limestone matrix. The calyx of one specimen (IGS 42P95) was freed successfully, however, in preparation so that it could be viewed from all sides before gluing back in place (Fig. 19,1a-d). This calyx is 3.7 mm. in height and has an estimated diameter of 3.0 mm. in undistorted condition. Only a few proximal brachials belonging to the A, B, and C rays remain in association with the calyx, but except for a short missing intermediate section of the stem, this is preserved in attached position to a distance of 39 mm. beneath the calyx. The transversely circular stem is seen to be essentially homeomorphic in successive portions but markedly xenomorphic from proximal to distal regions. Near the calyx the columnals are very low, with longitudinally rounded sides. Their height gradually increases downward until at distances of more than 8 mm. height nearly

![Fig. 18. Caecacrocrinus urnula Moore & Strimple, n. gen., n. sp.](image)

1-2. Camera lucida drawings of paratype (SUI 32940) seen from ventral side (primanal above) and AB-inter-ray view (A radial with subjacent longitudinal series of intercalary plates near right edge), both ×8.5.

3. Similar enlarged view of posterior side of calyx (primanal and subanal intercalary series slightly right of midline), ×17.
FIG. 19. _Caucaxromius urnula_ Moore & Strimple, n. gen., n. sp. (continued on facing page).

1. Specimen (paratype IGS 42P95) with proximal brachials preserved in some rays and long attached stem, illustrated by camera lucida drawings, all $\times 15$; 1a, calyx from _D-ray_ and primanal side with proximal part of stem (7.5 mm.) joined to basal circlet, showing gradual increase in height of columnals away from calyx, most
Moore, Strimple—Mississippian-Pennsylvanian Camerate Crinoids

equals diameter and sides of the columnals are nearly straight longitudinally. Intercolumnar sutures are slightly indented and on many columnals a very faint row of fine granules girdles them at mid-height. The articular facets are not clearly discernible, but appear to match those illustrated in Figures 16,7 and 17,8 in having a diminutive pentastellate lumen and fine peripheral crenulae.

Arm structure exhibited by paratype IGS 42P94 (Fig. 19,2a) indicates isomorbus bifurcation on primibrachs 2 or 3 (also indicated in Fig. 19,1b-c) and cuneate uniserial appearance of brachials with long pinnules, but the arms are judged to be actually biserial. The DE side of the calyx in this specimen is concealed. Height of the calyx is 3.8 mm. and its undistorted diameter is estimated to be 3.5 mm.

Illustrations.—Fig. 1,6. Diagram showing plate arrangement in upper part of calyx (radials black, distalmost intercalaries gray).—Fig. 16,1,7. Camera lucida drawings of holotype (IGS 42P87) in AB-interray, B-ray, CD-interray, D- and E-ray, ventral and dorsal views (anal pyramid shown in side views and oral plates and anal pyramid in ventral view), all \( \times 13.5 \).—Fig. 17,1,7-8. Camera lucida drawings of juvenile specimen (paratype IGS 42P88) in A-, B-, C-, and D-ray, CD- and DE-interray, ventral, and dorsal views, all \( \times 17 \) (anal pyramid shown in side and ventral views of calyx and orals seen as large plates of tegmen in fig. 7; CD interray directed upward in fig. 8).—Fig. 18,1,3. Camera lucida drawings of paratype (SUI 32940); 1,2, ventral and AB-interray views, \( \times 8.5 \); 3, posterior side of calyx (priminal and subanalar intercalary series slightly right of mid-line (anal pyramid broad and low), \( \times 17 \).—Fig. 19,1,2. Camera lucida drawings of paratypes attached to matrix; specimen IGS 42P95 (1a-h) with long stem and proximal parts of arms in 3 rays, all \( \times 15 \); specimen IGS 42P94 (2a-e) with short attached stem section and arms belonging to A, B, and C rays, all \( \times 7.5 \); 1a-d, primanal-D side of calyx with attached proximal section of stem, C-ray, AB-interray, and E sides of calyx; 1e, part of stem belonging next below 1a; 1f-h, distal sections of preserved part of stem (17 mm. of stem omitted between 1e and 1f, lg and 1h in sequence next below 1f; 2a-c, BC-interray, C, and B-ray views of crown.

Discussion.—As in other observed acrocrinids, juvenile individuals are differentiated from adults by their smaller size and smaller number of intercalary plates. In each, calyx elements and their arrangement appear to be identical.

Types.—Holotype, IGS 42P87a; paratypes, IGS 42P87b, IGS 42P88, IGS 42P94, IGS 42P95, SUI 32940. Collectors, H. L. Strimple and Christina Cleburn.

Occurrence.—LaSalle Limestone, Missourian, Upper Pennsylvanian, Oeoya quarry near Pontiac, Livingston County, Illinois.

CAUCAcrocrinus ACUTUS Moore & Strimple, n. sp.

Diagnosis.—Calyx with plate construction same as seen in Caucacrocrinus urnula but distinguished by straighter sides and more narrowly pointed base.

Description.—Although so far known only from the holotype, which is a complete calyx except for some of the parts of the tegmen, this seems clearly to represent a species distinct from Caucacrocrinus urnula. The radials are proximally truncate (narrowly so in the D ray) in all but the C ray, in which the radial is pointed proximally and not in series with an underlying subradial intercalary plate. As in C. urnula, the radial articular facets are narrowly arculate and occupy approximately one-third of the width of the radials. Associated with them in three rays are first primibrachs, slightly displaced inward.

2. Specimen (paratype IGS 42P94) with large part of arms and small proximal section of stem attached to calyx, camera lucida drawings, \( \times 7 \); 2a, crown viewed looking toward BC-interray side of calyx, arms branching isomorphously on axillary primibrach 2 or 3; 2h-e, calyx from C-ray and AB-interray sides (D and E rays not visible, concealed by matrix).
Fig. 20. Caucacocrinus acutus Moore & Strimple, n. gen., n. sp. (continued on facing page).
Because the holotype of *C. acutus* possesses abundant intercalaries, it is judged to be an adult specimen. The diminutive basal circlet has rather gently upflaring sides rather than steep ones (Fig. 20,1-6).

No anal pyramid is preserved and only two or three tegminal plates, interpreted as displaced orals, are associated with tiny plates. Information concerning summit features of the calyx is lacking.

Dimensions (in mm.) of the holotype specimen are as follows. Calyx: H, 3.3; W, 2.6. A radial: H, (mid-line), 0.8; H (interradial suture), 0.6; W, 1.2; articular facet W, 0.7. Subradial and subanal intercalary: H, 0.8; W, 0.9. Basal circlet: H, 0.2; W, 0.6.

**ILLUSTRATIONS.**—Fig. 20,1-7. Camera lucida drawings of holotype in A-, B-, C-, D-, and E-ray, CD-interray, and ventral views of calyx, all ×17 (CD interray directed upward in fig. 7).—Fig. 21,2a-c. Holotype in A-ray and CD-interray views, ×7.

**TYPE.**—Holotype, IGS 42P89; collected by Christina Cleburn.

**Occurrence.**—LaSalle Limestone, Missourian, Upper Pennsylvanian, Ocoya quarry near Pontiac, Livingston County, Illinois.

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**Genus METACROCRINUS Moore & Strimple, n. gen.**

**TYPE SPECIES.** — *Acrocrinus pumpkensis* Strimple, 1949, p. 900, fig. 2, pl. 1, fig. 1-3.

**DIAGNOSIS.**—Differs from *Dinacrocrinus* only in absence of intercalary plate directly beneath D radial (Fig. 1,8). Middle Pennsylvanian (Desmoinian).

**DESCRIPTION.**—The calyx is subglobular in shape, broadly rounded below and somewhat truncate at the summit. The radials and primplanal are distinctly, though not greatly larger than upper and intermediate intercalaries and lowermost intercalaries are unusually few (11 in the holotype of the type species) and large.

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**METACROCRINUS PUMPKENSIS** (Strimple),
Moore & Strimple, n. comb.

*Acrocrinus pumpkensis* Strimple, 1949, p. 900, fig. 2, pl. 1, fig. 1-3.

**DIAGNOSIS.**—Characters of genus.

**DESCRIPTION.**—The hexagonal radials (except pentagonal in D ray) are widest at mid-height and in all the height is only one half or less of width. These plates are especially characterized by their strongly curved articular facets, which occupy one-fourth of the summit radial width (Fig. 21,2b-c). The primanal (X) plate is somewhat larger than adjoining radials and has height equal to width; it is hexagonal in outline but appears almost quadrangular. The intercalaries are relatively large, even near the base of the calyx, and in accordance with this their aggregate number is comparatively small (62 in the holotype specimen). The flat basal circlet, 3.2 mm. in diameter, is nearly three times as wide as proximal columns, 1.2 mm. in width. Plates of the calyx are smooth and evenly confluent with neighbors, but sutures between them are very sharply defined.

Dimensions of the holotype (in millimeters), some slightly modified from first-published figures, are as follows. Calyx: H, 9.5; W, 7.5. A radial: H (at mid-width), 1.5; H (at interradial sutures), 1.0; W (maximum), 3.2; W (at base), 1.5. Primanal (X) plate: H, 2.9; W, 3.0.

**ILLUSTRATIONS.**—Fig. 1,8. Diagram of calyx plates (radials black, distalmost intercalaries gray) (Strimple, 1949, mod.)—Fig. 21,2a-c. Holotype in dorsal, D-ray (slightly left of mid-line), and E-A-interray views, all ×4 (Strimple, 1949).

**DISCUSSION.**—This species resembles *Dinacrocrinus expansus* Strimple in general shape of the calyx, large size of the intercalaries, and relatively small number of these plates—so much so that the difference in morphology of the D ray is not now reliably interpretable as a basis for generic distinction. Additional specimens of both species are needed to establish constancy of their structure as presently known.


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1-6. Camera lucida drawings of holotype specimen (IGS 42P89) in side views looking toward A, B, C, D, and E rays, and CD interray, all showing pointed lower extremity of calyx with low but distinctly visible basal circlet, all ×17.

7. Similar drawing of calyx summit showing some first primibrachs and displaced orals (primanal above and slightly toward left), ×17.
Occurrence. — Lake Murray Formation (Pumpkin Creek Limestone Member), lower Desmoinesian, Middle Pennsylvanian; west side of Lake Murray, south of Ardmore, Carter County, Oklahoma.

Genus DINACROCRINUS Moore & Strimple, n. gen.

Type Species.—Acrocrinus expansus Strimple, 1951, p. 192, fig. 1, 17-20; original designation herein.

Diagnosis.—Calyx rotund, truncate at summit of radials, basals barely visible from side or not visible; differing from Globacrocrinus in occurrence of 12 intercalaries next beneath radial circlet, 5 subradial, with longitudinal series of intercalaries under A radial and primanal (Fig. 1). Middle Pennsylvanian (Desmoinesian)—Upper Pennsylvanian (Missourian), USA (Oklahoma-Illinois).

Description.—Calyx with flat to very gently convex or concave base, approximately 0.6 of greatest calyx width located at about 0.35 of calyx height, where sides are strongly and evenly rounded, upper sides of calyx nearly vertical or sloping evenly inward to summit, which is 0.6 to 0.9 of greatest width in distance across between opposite radial margins.

Discussion.—Superficially, Dinacrocrinus resembles Globacrocrinus, for in shape and average dimensions of the calyx, as well as in the narrow width of the arcuate radial articular facets, one could almost be mistaken for the other. The prime distinction between the two genera is found in the number and arrangement of distalmost intercalary plates, which are 12 in Dinacrocrinus, with one such plate directly beneath each radial and the primanal, whereas in Globacrocrinus total plates in this circlet number eight, with only the A radial and primanal followed directly beneath by an intercalary plate. In so far as now known, Globacrocrinus is restricted to Lower and Middle Pennsylvanian formations, whereas Dinacrocrinus occurs in Middle and Upper Pennsylvanian beds.

DINACROCRINUS EXPANSUS (Strimple), Moore & Strimple, n. comb.

Acrocrinus expansus Strimple, 1951, p. 192, fig. 1, 17-20.

Diagnosis.—Characters of genus.

Description.—The shape of the calyx in this species is tomato-like, with flat, faintly concave base, strongly rounded lower sides, and evenly inward sloping upper sides. The holotype of the type species, which is 8.4 mm. high, has maximum width of 10.0 mm. and width at summit of the radials amounting to 6.2 mm. The radials and primanal, approximately 2 mm. high by 3 mm. wide, are very little larger than the upper and middle intercalary plates. The strongly arcuate radial facets occupy 0.7 of the distal width of these plates and their concave surface is nearly as broad from outer to inner edges as from lateral margins. Diameter of the basal circlet is 2 mm.

Illustrations.—Fig. 21,4a-d. Holotype in ventral, dorsal, CD-interray, and A-ray views, all ×4 (CD interray directed upward in fig. 4a and 4b) (Strimple, 1951). [Also see Fig. 1.7.]

Type.—Holotype, U. S. Natl. Museum, no. S4901. Collected by H. L. STRIMPLE.

Occurrence.—Oologah Ls., Desmoinesian, quarry about 7 miles east of Tulsa, Oklahoma.

DINACROCRINUS ELEGANS (Strimple), Moore & Strimple, n. comb.

Acrocrinus elegans Strimple, 1949, p. 903, pl. 1, fig. 4-6, text-fig. 2.

Diagnosis.—Characters of genus but differing from its type species in having slightly upflaring basals which are visible from side and in relatively tall urn-shaped form of calyx; tegmen with low anal pyramid near posterior margin.

Description.—The slightly deformed holotype specimen, which is the only representative of the species yet found, is evenly rounded in its lower part and nearly vertical-sided from mid-height of the calyx to the summit of the radial circlet. Height of the calyx is 9.3 mm. and greatest width approximately 7.0 mm. The intercalaries are smaller in average size than in Dinacrocrinus expansus and more numerous.

Illustrations.—Fig. 21,1a-c. Holotype in A-ray, CD-interray, and dorsal views of calyx, all ×4 (CD interray directed upward in fig. 1c) (Strimple, 1949).

Type.—Holotype, U. S. National Museum no. S4750. Collected by H. L. STRIMPLE.

Occurrence.—Shale above Torpedo Sandstone, Ochelata Group. Upper Pennsylvanian (upper Missourian), 2.5 miles NE of Copan, Washington County, Oklahoma.
**DINACROCRINUS WORTHENI**
(Wachsmuth), Moore & Strimple, n. comb.

*Acrocirinus wortheni* Wachsmuth, 1882, p. 41.—
Wachsmuth & Barris, 1883, p. 343, pl. 30, fig. 13.
—Wachsmuth & Springer, 1885, p. 125, pl. 9, fig. 1; 1897, p. 807, pl. 80, fig. 10a-b.—Springer, 1926, p. 45, pl. 12, fig. 10.

**Diagnosis.**—Differs from type and other species of genus in diminutive size of calyx, its subvertical sides, and width at summit nearly equal to maximum width and that just above flatly rounded base.

**Description.**—Height and maximum width of the calyx are about 5.5 mm. and 5.3 mm., re-

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**Fig. 21. Dinacrocrinus, Metacrocrinus, and Caucacrocrinus, all Moore & Strimple, n. gen.**

1. *Dinacrocrinus elegans* (Strimple), Moore & Strimple, n. comb.; holotype specimen (USNM 54750); 1a-c, A-ray, CD-interray, and dorsal views of calyx (CD interray directed upward in 1c); all X4 (Strimple, 1949).

2. *Metacrocrinus pumphensis* (Strimple), Moore & Strimple, n. comb.; holotype (USNM 54749); 2a-c, dorsal view (CD interray directed upward), posterior side of calyx (primanal slightly right of mid-line), and EA-interray view of calyx, all X4 (Strimple, 1949).

3. *Caucacrocrinus acutus* Moore & Strimple, n. sp., holotype (IGS 42P89); 3a-b, side views of calyx looking toward A ray and CD interray, X7.

4. *Dinacrocrinus expansus* (Strimple), Moore & Stripple, n. comb.; holotype (USNM 54901); 4a-d, ventral and dorsal views of calyx (both with CD interray directed upward), and side views looking toward CD interray and A ray, all X4 (Strimple, 1951).
spectively. The radials are appreciably wider than high and have broadly arcuate articular facets. Intercalaries mostly hexagonal in outline and except near the base of the calyx fairly similar in size. Their arrangement exactly conforms to that given in diagnosis of the genus, with 12 plates in the distalmost circlet and longitudinal series beneath the A radial and primanal. Despite the small size of the calyx, the holotype contains 86 plates (5 radials, primanal, 2 basals, 78 intercalaries) (Fig. 22,1).

ILLUSTRATIONS.—Fig. 22,1-3. Holotype specimen; 1, plate diagram (modified from Wachsmuth & Springer, 1885); 2-3, A-ray and BC-interray side views of calyx, X12 (after Wachsmuth & Barris, 1883).

TYPE.—Holotype (only recorded specimen), originally repositioned in Illinois State Museum at Springfield, now Illinois Geological Survey, no. IGS 2469.

OCCURRENCE.—Exact stratigraphic and geographic source of type is unknown. Because merely reported from "Upper Coal Measures, Peoria County, Illinois." According to H. R. Wanless, marine Pennsylvanian strata of this county include the St. David, Breerton, and Lonsdale limestones (upper Desmoinesian) and Trivoli Limestone (lower Missourian). Thus, Dinacrocrinus wortheni may belong either to upper Middle Pennsylvanian, approximately equivalent in age to D. expansus, or to lowermost Upper Pennsylvanian, corresponding more or less closely to the horizon of D. elegans.

PROTACROCRINUS Moore & Strimple, n. gen.


Diagnosis.—Crown pyriform, with ten biserial arms bearing long slender pinnules. Calyx deep bowl-shaped, evenly rounded at base, truncate at top, composed of five small radials which are subequal in height and width, primanal rising slightly above summit of radials, six tall intercalaries directly beneath radials and primanal, and two basals (Fig. 1,2). Stem impression very small, stem unknown. Lower Mississippian (Kinderhookian).

Discussion.—As noted in general discussion of the Acrocrinidae, Protacrocrinus is the oldest known representative of the family and its complement of only 14 plates in the calyx makes this genus decidedly the most simple in structure. Protacrocrinus is not smallest in size, for the height and diameter of the calyx of P. primitivus are two or three times greater than corresponding measurements of Planacrocrinus minitus and Caucacrocrinus acutus. The shape of the calyx differs little from that of the former species and some forms of Globacrocrinus.

PROTACROCRINUS PRIMITIVUS (Laudon & Beane), Moore & Strimple, n. comb.

Acrocrinus primitivus Laudon & Beane, 1937, p. 252, pl. 17, fig. 5-6.

Diagnosis.—Characters of genus.

Description.—The relatively tall, transversely subcircular calyx is chiefly characterized by its evenly rounded base, with basal circlet nearly one-third of total calyx height (Fig. 23,2-7; 24,1a-b). The radials are small plates which in views directly normal to their mid-points and with summit margins drawn straight from shoulder to shoulder (ignoring deeply arcuate articular facets) are hexagonal in the C and D rays and pentagonal in others (Fig. 23,1). The A and B radials are distinctly smaller than the intercalaries beneath them, whereas the C, D, and E radials are approximately equal in size to the subradial intercalaries associated with them. These intercalaries are quadranuclear in the C and D rays, pentagonal in the E ray, and hexagonal in others (Fig. 23,2-5,7). All are taller than wide. The A, E, and subanal intercalaries are slightly offset toward right, with oblique shoulders at upper right margins (Fig. 23,2,6-7). The A and CD intercalaries are pointed at their lower edges to match beveled shoulders of the basals next to the interbasal suture. The strongly curved radial articular facets are narrow, occupying little more than one-third of the radial summit. All calyx plates are smooth. Sutures between them are distinct but not impressed.

The arms are very well rounded externally. Primibrach 1 and axillary primibrach 2 are low plates, less than half of width in height. They lack pinnules. Lowermost brachials of the ten arms are cuneate in shape, with pinnules borne by upper angles of their taller margins, Biserial structure of the arms is attained at levels of the fourth or fifth secundibrachs. The long slender pinnules are composed of short pinnulars, with
length 1.5 to 2 times width. The arms of the holotype rise almost vertically from the calyx, curve outward, and toward summit of the crown bend inward. They are nearly uniform in narrow width throughout most of their height, but as expected taper somewhat distally.

A small stem impression is barely perceptible.

Dimensions of the crown, calyx, and plate elements of the holotype of Protacrocrinus primitivus expressed in millimeters and given in terms of height (H), width (W), diameter (D), and length (L) are as follows. Crown: H, 25. Calyx: H, 7.0; D, 5.0. Radials, given as H and (W): A, 2.7 (3.1); B, 2.3 (2.3); C, 2.5 (2.8); D, 1.9 (2.3); E, 2.3 (2.3). Primanal: H, 1.9; W, 1.5. Intercalaries, given as for radials: A, 4.1 (2.5); B, 3.8 (3.1); C, 2.8 (1.8); D, 2.3 (1.8); E, 2.8 (2.1); subanal, 4.1 (2.3). Basal circlet: H, 1.9; D, 3.7.

Illustrations.—Fig. 23, 1-7. Camera lucida drawings of holotype and component elements of its calyx, all ×8.5; 1, radial and primanal plates viewed perpendicularly toward their mid-points (broken lines across arcuate articular facets of radials; 2-7, side views of calyx from A, B, C, D, E, 7.
Fig. 23. Protacrocinus Moore & Strimple, n. gen. (continued on facing page).
CD, and E rays and interray.—Fig. 24, la-b. Holotype crown viewed from B- and D-ray sides, X2.25. [Also see Fig. 1,2.]

Type.—Holotype, SUI 2144, collected by B. H. Beane.

Occurrence.—Hampton Formation, Lower Mississippian (Kinderhookian), LeGrand, Tama County, Iowa.

**SPRINGERACROCRINUS Moore & Strimple, n. gen.**

**Type Species.** — Acrocrinus intermedius Springer, 1926, p. 43.

Diagnosis.—Calyx subconical, urn-shaped, widest at summit; otherwise with characteristics of genus.

Description.—The radial plates are pentagonal in outline, with height little less than width, their average height amounting to one-third that of the calyx; their arcuate articular facets are narrow, occupying only one-fourth to one-third of the distal margin of the radials, with shoulders on either side subhorizontal or sloping very gently downward to the interradial sutures (Fig. 24,3-6).

The hexagonal primanal (X) plate is somewhat wider and a little taller than the radials and is distinguished by its very wide, gently curved summit margin next to a low anal pyramid at the posterior edge of the tegmen. The intercalary plates range in shape from pentagonal to hexagonal or heptagonal. All are distinctly smaller than the radials. Outer parts of the basal plates slope steeply upward in line with curvature of the calyx sides; the height of peripheral parts of these plates may exceed the diameter of the basal circle at its horizontal lower portion. All plates of the calyx are smooth and either plane or very slightly tumid.

The slender, externally well-rounded arms bifurcate evenly on primibrach 2 and commonly in one of the branches on secundibrach 2. The brachials are uniserially arranged beneath the axillary secundibrach of branched arms and near the base of the unbranched arm above an axillary primibrach and all of these lack pinnules. Distally, the brachials first become cuneate in external outline and then quickly assume a biserial arrangement, each brachial in these parts of the arms bearing very long slender pinnules. The pinnules are composed of unusually long narrow pinnulars. In such specimens the distal parts of the arms curve strongly inward at summit of the crown.

1. Protacrocrinus primitivus (Laudon & Beane), Moore & Strimple, n. comb.; camera lucida drawings of radials and primanal viewed perpendicularly to centers of these plates (broken lines drawn straight across arcuate radial articular facets from their lateral margins for the purpose of indicating shape of these plates in overall outline), X8.5.

2-7. Same, calyx and proximal arm extremities of holotype specimen (SUI 2144); camera lucida drawings of A-, B-, C-, and D-ray, CD-interray, and E-ray sides of calyx showing varied shapes of intercalaries and bowl-like bipartite basal circle, all X8.5.
The slender part of the stem near the base of the calyx is composed of very low columnals. In intermediate and distal parts of the stem the columnals increase in height and diameter, with longitudinally even-rounded sides. The nature of the columnal articular facets and axial canal is not recorded.

Dimensions of specimens illustrated by Springer (1926, pl. 12) are as follows. Crown: H, 21 (fig. 2), 28 (fig. 5). Calyx (respectively fig. 2-5): 7, 6, 7, 7; W, 5, 5, 5, 6. Primanal (fig. 2): H, 2.0; W, 2.2. Average radial: H, 1.5, 1.7, 2.5, 2.0; W, 1.5, 2.0, 2.5, 2.0. Basal circlet: H, 1.5: W, 2.5.

ILLUSTRATIONS.—Fig. 24,3-6. Side views of type specimens; 3, lectotype crown viewed from C-ray side, primanal and subanal intercalary series near left edge of photo, X3.4. 4-5, C- and F-ray views of paralectotypes, X3.4; 6, A-ray view of paralectotype crown, X1.7 (Springer, 1926). [See Fig. 1,10 also.]

TYPES.—Syntypes (SI578) reposed in Springer collection, U. S. National Museum. The specimen illustrated by Springer (1926) in figure 2 of his plate 12 is here designated as the lectotype and others as paralectotypes.

Occurrence.—Renault Formation, Upper Mississippian (lower Chesteran), near Burksville, Monroe County, Illinois.

SPRINGERACROCRINUS MJATSCHKOWENSIS (Yakovlev), Moore & Strimple, n. comb.

Acrocinnus mjatschkowensis Yakovlev, 1926, p. 47, fig. 3-4.—Yakovlev & Ivanov, 1956, p. 34, pl. 8, fig. 7a-b.

Diagnosis.—Construction of radial circket and large primanal in CD interray, arrangement of distalmost intercalaries, occurrence of subanal intercalaries in longitudinal series, and bipartite basal circket with upflaring periphery all as in Springeracrocrinus intermedius, but distinguished from this species by tall sausagelike, ovoid form of calyx and large number of nearly even-sized intercalaries.

Description.—Most of the sides of the calyx representing Springeracrocrinus mjatschkowensis are nearly straight and vertical but toward the summit and base they curve inward to produce rounded extremities (Fig. 24,7b). The pentagonally shaped radials have subequal height and width and are narrowest at distal margins which are indented by arcuate articular facets narrower than the summit width of these plates. The primanal is slightly larger than the radials, hexagonal in outline, and its distal edge is slightly below the level of the radial summits. Beneath it in longitudinal series are three subanal intercalaries but lower plates on the posterior side of the calyx do not continue this series. Nine or ten transversely disposed circllets of intercalaries are recognized, with moderate regularity in their arrangement.

Dimensions (in mm.) of the calyx and component elements are as follows. Calyx: H, 10.3; W, 5.1. Radials (average) H and W, 1.7. Primanal: H, 1.7; W, 2.0. Basal circket: H, 0.8; W, 3.5.

Discussion.—Despite dissimilarity of Springeracrocrinus mjatschkowensis in shape of its calyx as compared with S. intermedius and S. praecursor, with very little hesitation the Russian species is considered congeneric with the American ones. Chief interest lies in its very elongate modified calyx form and large number of intercalary plates, along with this is its occurrence in eastern Europe in beds approximately equivalent to Middle Pennsylvanian of the United States.

ILLUSTRATIONS.—Fig. 24,7a-b. Ventral and CD-interray views of type specimen, X4.5 (Yakovlev & Ivanov, 1956).

Occurrence.—Middle Carboniferous (Myachkovian) (Cam). Moscow basin, southeast of Moscow, USSR.

SPRINGERACROCRINUS PRAECURSOR (Springer), Moore & Strimple, n. comb.

Acrocinnus praecursor Springer, 1926, p. 42, pl. 12, fig. 1.

Diagnosis.—Differs from Springeracrocrinus intermedius chiefly in larger number of intercalaries, straight slender arms composed of cuneate uniserial brachials alternately bearing pinnules on opposite sides of arms, seemingly ten but branching just above calyx not preserved.

Description.—This species is based on a single incomplete crown with somewhat crushed calyx, which is deeply subconical, as in Springeracrocrinus intermedius (Fig. 24,2). Its quadrilateral radials are subequal in height and width, with comparatively shallow arcuate articular facets. The primanal (X) plate resembles these but is hexagonal in outline and directly
1. *Protacrocrinus primitivus* (Laudon & Beane), Moore & Strimple, n. comb.; holotype crown (SUI 2144); 1a-b, views of specimen from B- and D-ray sides, ×2.25 (Moore & Strimple, new).

2. *Springeracrocrinus praecursor* (Springer), Moore & Strimple, n. comb.; holotype (USNM S1779), showing posterior side of crown (primanal centrally located at summit of calyx), somewhat crushed specimen with well-marked upflaring equal basals, ×1.7 (Springer, 1926).

3-6. *Springeracrocrinus intermedius* (Springer), Moore & Strimple, n. comb.; lectotype (USNM S1578a (fig. 3) and paralectotypes (USNM S1578b-d) (fig. 4-6); 3, crown viewed from C-ray side (primanal and subanal intercalary series near left edge of photo), ×3.4; 4-5, C- and E-ray views of calices showing tall upflared basal circlet, ×3.4; 6, A-ray view of crown, ×1.7 (Springer, 1926).

7. *Springeracrocrinus mjatschkowensis* (Yakovlev), Moore & Strimple, n. comb.; type specimen; 7a-b, ventral and CD-interray views of calyx with associated first primibrachs, ×4.5 (Yakovlev & Ivanov, 1956).

Fig. 24: *Protacrocrinus* and *Springeracrocrinus* Moore & Strimple, n. gen.
underlain by a series of intercalaries. Other intercalary plates in the distal most circlet are interradial but arrangements of these plates in lower circlets becomes disordered. The basal circlet is truncated proximally and has steeply upflaring sides.

Dimensions (in mm.) of the type specimen are as follows. Calyx: H, 9.0 (illustration given by Springer, reported to be ×1, is actually ×2); W, 7.5. Radials (average): H, 2.5; W, 2.5. Basal circle: H, 1.5; W, 3.5.

Illustrations.—Fig. 24,2. Posterior view of crown, ×1.7 (Springer, 1926).

Type.—Holotype (S1779) reposition in U. S. National Museum.

Occurrence.—Upper Burlington Limestone, Lower Mississippian (Osagian), Burlington, Iowa.

REFERENCES


