Phylogeny and evolutionary history of diplobathrid crinoids (Echinodermata):

Supplemental Data

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Supplemental Tables

Supplemental Table 1. Traditional higher classification of taxa included in the phylogenetic analysis and references used to supplement coding from museum specimens. *A Treatise on Invertebrate Paleontology* was also used as a coding reference for most taxa. Asterisk (*) denotes non-type species coded; dagger (†) denotes taxa erroneously assigned to Dimerocrinitidae in their original descriptions that are here considered members of Rhodocrinitidae on the basis of radial circlet morphology.

Genus and Species Coded	Higher Classification	Superfamily	Family	Coding References
*Euptychocrinus skopaios** Brower, 1994	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Brower, 1994
Ptychocrinus splendens (Miller, 1883)	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Wachsmuth & Springer, 1897; Brower, 1973
Rosfacrinus robustus Le Menn & Spjeldnaes, 1996	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	LeMenn & Spjeldnaes, 1996
Allozygocrinus dubuquensis Witzke & Strimple, 1981	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Witzke & Strimple, 1981
Ambicocrinus arborescens (Talbot, 1905)	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Kirk, 1945; Goldring, 1923
Apurocrinus sucrei McIntosh, 1981	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	McIntosh, 1981; Thompson et al., 2013
Becsciecrinus adonis Ausich & Copper, 2010	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Ausich & Copper, 2010
Cybelecrinus ladas Ausich & Copper, 2010	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Ausich & Copper, 2010
Dimerocrinites brachiatus (Hall, 1852)	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Wachsmuth & Springer, 1897
Dimerocrinites decadactylus Phillips in Murchison, 1839	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Donovan et al., 2012
Duncanicrinus calvariolus Jell, 1999	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Jell, 1999
Eodimerocrinites littlewoodi Donovan & Gilmour, 2003	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Donovan & Gilmour, 2003
*Eucrinus clarkae** Jell, 1999	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Jell, 1999
Eudimerocrinus multibrachiatus Springer, 1926	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Springer, 1926
Griphocrinus nodulosus (Hall, 1862)	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Wachsmuth & Springer, 1897; Goldring, 1923

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Genus and Species Coded	Higher Classification	Superfamily	Family	Coding References
Hiiumaacrinus vinni Ausich & Wilson, 2016	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Ausich & Wilson, 2016
Macarocrinus spirngeri Jaekel, 1895	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Jaekel, 1895; Opitz, 1932
Nexocrinus delicatulus Witzke & Strimple, 1984	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Eckert, 1984
Pterinocrinus quinquenodus Goldring, 1923	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Goldring, 1923
Shidianocrinus conicus Chen et al., 1985	Diplobathrida	Dimerocrinitoidea	Dimerocrinitidae	Chen et al., 1985; Webster et al., 2009
Cyphocrinus gorbyi Miller, 1892a	Diplobathrida	Dimerocrinitoidea	Elpidocrinidae	Springer, 1926
Elpidocrinus tholiformis Strimple, 1963	Diplobathrida	Dimerocrinitoidea	Elpidocrinidae	Frest & Strimple, 1981
Pelidocrinus exiguus (Strimple, 1963)	Diplobathrida	Dimerocrinitoidea	Elpidocrinidae	Frest & Strimple, 1981
Pidelocrinus planus Frest & Strimple, 1981	Diplobathrida	Dimerocrinitoidea	Elpidocrinidae	Frest & Strimple, 1981
Gazacrinus inornatus Miller, 1892a	Diplobathrida	Dimerocrinitoidea	Gazacrinidae	Wachsmuth & Springer, 1897; Springer, 1926
Pregazacrinus hemisphericus Witzke & Strimple, 1981	Diplobathrida	Dimerocrinitoidea	Gazacrinidae	Witzke & Strimple, 1981
Lampterocrinus tennesseensis Roemer, 1860a	Diplobathrida	Dimerocrinitoidea	Lampterocrinidae	Springer, 1926
Siphonocrinus nobilis (Hall, 1861)	Diplobathrida	Dimerocrinitoidea	Lampterocrinidae	Wachsmuth & Springer, 1897
*Orthocrinus primaevus** Le Menn, 1980	Diplobathrida	Dimerocrinitoidea	Orthocrinidae	Le Menn, 1980, 1985
Nyctocrinus magnitubus Springer, 1926	Diplobathrida	Nyctocrinoidea	Nyctocrinidae	Springer, 1926
Aishacrinus carus Prokop, 2010	Diplobathrida	Rhodocrinitoidea	Aishacrinidae	Prokop, 2010
*Anthemocrinus minor** (Angelin, 1878)	Diplobathrida	Rhodocrinitoidea	Anthemocrinidae	Angelin, 1878
Turbocrinus punctum Ausich, 1986a	Diplobathrida	Rhodocrinitoidea	Anthemocrinidae	Ausich, 1986a
Wilsonicrinus discoideus Springer, 1926	Diplobathrida	Rhodocrinitoidea	Anthemocrinidae	Springer, 1926
Anthracocrinus primitivus Strimple & Watkins, 1955	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Strimple & Watkins, 1955; Kolata, 1982
Dalicrinus hammanii Cole et al., 2016	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Cole et al., 2017
Fombuenacrinus nodulus Cole et al., 2016	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Cole et al., 2017
Goyacrinus gutierrezi Cole et al., 2017	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Cole et al., 2017
Gustabilicrinus plektanikaulos Guensburg, 1984	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Guensburg, 1984, 1992a
Hercocrinus ornatus Hudson, 1907	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Hudson, 1907

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Genus and Species Coded	Higher Classification	Superfamily	Family	Coding References
Priscillacrinus elegans Cole et al., 2018	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Cole et al., 2018
Rheocrinus aduncus Haugh, 1979	Diplobathrida	Rhodocrinitoidea	Anthracocrinidae	Haugh, 1979
Deocrinus asperatus (Billings, 1859)	Diplobathrida	Rhodocrinitoidea	Anthroacocrinidae	Hudson, 1907
Callistocrinus tesselatus Eckert & Brett, 2001	Diplobathrida	Rhodocrinitoidea	Callistocrinidae	Eckert & Brett, 2001
Cleiocrinus regius Billings, 1957a	Diplobathrida	Rhodocrinitoidea	Cleiocrinidae	Springer, 1905
Emperocrinus indianensis Miller & Gurley, 1895	Diplobathrida	Rhodocrinitoidea	Emperocrinidae	Miller & Gurley, 1895a; Springer, 1926
Peremocrinus depressus (Weller, 1900)	Diplobathrida	Rhodocrinitoidea	Emperocrinidae	Weller, 1900; Frest & Strimple, 1981
Tormosocrinus furberi Eckert & Brett, 2001	Diplobathrida	Rhodocrinitoidea	Emperocrinidae	Eckert & Brett, 2001
Hollowaycrinus calvus Jell, 1999	Diplobathrida	Rhodocrinitoidea	Opsiocrinidae	Jell, 1999
Opsiocrinus mariana Kier, 1952	Diplobathrida	Rhodocrinitoidea	Opsiocrinidae	Kier, 1952, 1958; Kesling & Meyer 1963; Kesling, 1968
Rhachicrinus wrighti Ausich, 1986a	Diplobathrida	Rhodocrinitoidea	Opsiocrinidae	Ausich, 1986a
Sakucrinus krossi Cole & Toom, 2018	Diplobathrida	Rhodocrinitoidea	Opsiocrinidae	Cole & Toom, 2018
Silfonocrinus siluricus Ausich, 1986a	Diplobathrida	Rhodocrinitoidea	Opsiocrinidae	Ausich, 1986a
*Acanthocrinus spinosus** (Hall, 1862)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Goldring, 1923
Ambonacrinus decorus Cole et al., 2017	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Cole et al., 2017
Apoarchaeocrinus anticostiensis Ausich & Copper, 2010	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich & Copper, 2010
*Archaeocrinus microbasalis** (Billings, 1857)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1897
Atactocrinus wilmingtonensis Weller, 1916	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Weller, 1916
Balacrinus basalis (M'Coy, 1850)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ramsbottom, 1961
Bromidocrinus nodosus Kolata, 1982	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Kolata, 1982
Bucucrinus saccus Ausich & Copper, 2010	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich & Copper, 2010
Cadiscocrinus southworthi Kirk, 1945	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Kirk, 1945
Cefnocrinus samgilmouri Botting, 2003	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Botting, 2003; Donovan & Gilmour, 2003
Condylocrinus verrucosus Eichwald, 1860	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Arendt, 1971
Cotylacrinna sandra Brower, 1994	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Brower, 1994

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Cribanocrinus wortheni (Hall, 1858)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Watchsmuth & Springer, 1897; Kirk, 1944
Crinerocrinus parvicostatus Kolata, 1982	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Kolata, 1982
*Diabolocrinus arbucklensis** Kolata, 1982	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Kolata, 1982
*Diamenocrinus primaevus** Le Menn, 1970	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Le Menn, 1985
*Gilbersocrinus tuberculosus** (Hall, 1859)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1897
*Gilbertsocrinus tuberosus** (Lyon & Casseday, 1859)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1897
Gnarycrinus lanei† Webster & Waters, 2009	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Webster & Waters, 2009; Waters et al., 2003
Kyreocrinus constellatus Ausich, 1986a	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich, 1986a
Lemennocrinus truyosi Pidal, 1984	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Pidal, 1984
Lutocrinus boliviensis† Thompson et al., 2013	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Thompson et al., 2013
Luxocrinus simplex Witzke & Strimple, 1981	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Witzke & Strimple, 1981
*Lyriocrinus melissa** (Hall, 1863)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1897
Maquoketocrinus ornatus Slocom, 1924	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Slocom in Slocom & Foerste, 1924
Moniellocrinus alcaldei Pidal, 1984	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Pidal, 1984
Neoarchaeocrinus pyriformis (Billings, 1857)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Billings, 1859; Wachsmuth & Springer, 1897; Strimple & Watkins, 1955
Ophiocrinus strangeri Sharpe & Salter, 1856	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Jell & Theron, 1999
Ortsaecrinus cocae Gil et al., 1999	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Gil et al., 1999; Ausich et al., 2002
*Paradiabolocrinus stellatus** Kolata, 1982	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Kolata, 1982
Paragazacrinus rotundus Springer, 1926	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Springer, 1926
Pararchaeocrinus decoratus Strimple & Watkins, 1955	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Strimple & Watkins, 1955; Kolata, 1982
Perunocrinus brachialis Prokop, 1986	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Prokop, 1986
Preschericrinus walsdorfensis Hauser, 2004	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Hauser, 2004
Probalocrinus dignis Clement & Brett, 2015	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Clement & Brett, 2015
Proexenocrinus inyoensis Strimple & McGinnis, 1972	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Strimple & McGinnis, 1972; Ausich, 1985, 1986b
*Rhaphanocrinus sculptus** (Miller, 1882)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1885, 1897; Walcott, 1882

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Rhipidocrinus crenatus (Goldfuss, 1831)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Breimer, 1960; Hauser, 1997
*Rhodocrinites kirbyi** (Wachsmuth & Springer, 1889)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Wachsmuth & Springer, 1897
Rhodocrinites nortoni (Goldring, 1933)	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Goldring, 1933
Simplococrinus persculptus Frest et al., 1976	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Frest et al., 1976; Kelly et al., 1978
Sphaerotocrinus ornatus Goldring, 1923	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Goldring, 1923
Stereoaster squamosus Foerste, 1919	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich, 1986a
Thylacocrinus vannioti Oehlert 1878	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Oehlert, 1878, 1882; Le Menn, 1985
Trichinocrinus terranovicus Moore & Laudon, 1943	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Moore & Laudon, 1943; Ausich et al., 1998
Ursucrinus stellatus Ausich & Copper, 2010	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich & Copper, 2010
Visocrinus castelli Ausich et al., 2002	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Ausich et al., 2002
Yunnanocrinus cyathomorphus Chen & Yao, 1993	Diplobathrida	Rhodocrinitoidea	Rhodocrinitidae	Chen & Yao, 1993; Webster et al., 2009
Spyridiocrinus cheuxi Oehlert, 1889	Diplobathrida	Rhodocrinitoidea	Spyridiocrinidae	Oehlert, 1889, 1890; Ubaghs, 1950
Paulocrinus biturbinatus Springer, 1926	Diplobathrida	Rhodocrinitoidea	Uncertain	Springer, 1926
Abludoglyptocrinus charltoni (Kolata, 1975)	Monobathrida	Glyptocrinoidea	Glyptocrinidae	Kolata 1975
Glyptocrinus decadactylus Hall, 1847	Monobathrida	Glyptocrinoidea	Glyptocrinidae	Wachsmuth & Springer, 1897
*Pycnocrinus dyeri** (Meek, 1872)	Monobathrida	Glyptocrinoidea	Glyptocrinidae	Miller, 1883; Wachsmuth & Springer, 1897
Celtocrinus ubaghsi Donovan & Cope, 1989	Monobathrida	Unknown	Unknown	Donovan & Cope, 1989
Eknomocrinus wahwahensis Guensburg & Sprinkle, 2003	Stem Eucamerate	N/A	Eknomocrinidae	Guensburg & Sprinkle, 2003
*Gaurocrinus nealli (*Hall, 1866)	Stem Eucamerate	N/A	Reteocrinidae	Wachsmuth & Springer, 1897; Springer, 1905
Quechuacrinus tisca Guensberg & Waisfeld, 2015	Stem Eucamerate	N/A	Reteocrinidae	Guensburg & Waisfeld, 2015
*Reteocrinus alveolatus** (Miller & Gurley, 1894)	Stem Eucamerate	N/A	Reteocrinidae	Springer, 1911; Guensburg, 1984

Supplemental Table 2. Characters and character states for phylogenetic analysis of diplobathrid crinoids

1. Symmetry: (0) pentameral (undifferentiated posterior); (1) bilateral symmetry (differentiated posterior).
2. Calyx height/width: (0) very high (> 2.0); (1) high (2.0 to >1.25); (2) medium (<1.25 to >0.75); (3) low (<0.75 to >0.50); (4) flat (< 0.50- >0.25); (5) very flat (<0.25).
3. Calyx profile: (0) straight sides; (1) convex sides.
4. Widest point in calyx: (0) top of calyx; (1) below top of calyx.
5. Calyx plate thickness measured on radial plate: (0) thin (<25% height or width); (1) thick (>25% height or width).
6. Calyx plate cross-sectional shape: (0) flat; (1) convex.
7. Calyx plate sculpturing: (0) smooth; (1) nodose; (2) granulose; (3) irregular nodes and pitting; (4) pitted; (5) ridges; (6) stellate ridges; (7) spines.
8. Sculpturing at base of calyx: (0) absent; (1) present
9. Calyx base sculpturing type: (0) nodose; (1) broken ridge/coalesced nodes; (2) circular ridge; (3) straight-sided ridge.
10. Width/flattening of calyx base: (0) narrow (base approximately as wide as stem); (1) expanded (~30-50% max calyx width; (2) flat-bottomed (>50% max calyx width).
11. Shape of circlet(s) at base of calyx: (0) upright; (1) flat; (2) concave.
12. Calyx lobation at the position where arms become free: (0) absent; (1) present.
13. Short ray lobes built with fixed brachials: (0) absent; (1) present.
14. Calyx sutures: (0) surface flush between adjacent plates; (1) impressed in a groove.
15. Infrabasal circlet: (0) absent; (1) present.
16. Infrabasals restricted to basal concavity: (0) no; (1) yes.
17. Infrabasals visible in side view: (0) no; (1) partially; (2) entirely.
18. Number of infrabasal plates: (0) five; (1) four; (2) three; (3) one.
19. Infrabasal plate dimensions: (0) width>height; (1) height≈width; (2) height>width.
20. Basals part of basal concavity: (0) no; (1) yes.
21. Basals visible in side view: (0) partially; (1) entirely; (2) no.
22. Number of basal plates: (0) five; (1) four; (2) three.
23. Basal plate dimensions: (0) width>height; (1) height≈width; (2) height>width.
24. Relative sizes of basal plates (excluding CD basal): (0) equal; (1) subequal/unequal.
25. Basals in sutural contact with interray plate(s) in regular interrays: (0) no; (1) yes.
26. CD basal plate differentiated from others: (0) no; (1) yes.
27. Radial circlet interruption: (0) absent; (1) CD interray only; (2) all interrays; (3) irregularly interrupted.
28. Radials in contact with infrabasals (radials and basals in a single circlet): (0) no; (1) yes.
29. Radial plate dimensions: (0) width>height; (1) height≈width; (2) height>width.
30. Radial circlet visible in side view: (0) completely visible; (1) partially visible; (2) not visible.
31. Radials part of basal concavity: (0) no; (1) yes.
32. Radial plates unequal in size: (0) no; (1) yes.
33. Relative size of radials, basals, and first interray plates: (0) unequal; (1) equal.
34. Relative size of radials and basals: (0) basal largest; (1) approximately equal; (2) radial largest

35. Largest plates in calyx: (0) basals; (1) radials; (2) first interray plates.
36. Fixed interray plates present in regular interrays: (0) absent; (1) present.
37. Competency of interrays: (0) Not competent, flexible, easily deformed/crushed; (1) competent, cemented, rigid.
38. Interray plating: (0) regular; (1) irregular.
39. Interray plating, if irregular: (0) large, regular plates with irregular accessory plates; (1) large pates, plating inconsistent between interrays.
40. Interray profile: (0) widest at top; (1) constricted at top; (2) maintains approximately equal width.
41. Number of interray plates in first row: (0) single plate; (1) multiple plates.
42. Dimensions of first interray plate (NA if multiple plates in first row): (0) width>height; (1) height≈width; (2) height>width.
43. Plates above first interray plate: (0) absent; (1) present.
44. Number of plates in second row: (0) two plates; (1) three plates; (2) one plate; (3) more than three plates.
45. Approximate number of regular interradial plates: (0) one to four; (1) five to twelve; (2) more than twelve.
46. Size of interray plates relative to adjacent fixed brachials: (0) roughly equivalent or larger in size; (1) much smaller than fixed brachial plates
47. Regular interrays depressed: (0) no; (1) yes.
48. Regular interrays with plating in biseries: (0) no; (1) yes.
49. Regular interrays in contact with tegmen: (0) absent; (1) present.
50. First posterior plate well defined as primanal: (0) no; (1) yes.
51. Accessory plates flanking primanal: (0) no; (1) yes.
52. Primanal in contact with CD basal: (0) no; (1) yes.
53. Primanal in contact with C and D radials: (0) neither; (1) both; (2) C radial only.
54. Primanal offset: (0) no; (1) yes.
55. Primanal dimensions: (0) width>height; (1) height≈width; (2) height>width.
56. Number of plates in second row following primanal (NA if primanal offset or undefined): (0) none; (1) one; (2) two; (3) three; (4) more than three.
57. Posterior interray profile: (0) widest at top; (1) constricted at top; (2) maintains approximately equal width.
58. CD interray differentiated from other interrays: (0) no; (1) yes.
59. Extra plates in CD interray: (0) no; (1) yes.
60. CD interray width in comparison with regular interrays: (0) same width; (1) wider.
61. CD interray in contact with tegmen: (0) absent; (1) present.
62. Anitaxis plating: (0) absent; (1) present.
63. Anitaxial ridge: (0) absent; (1) present.
64. Origin of anitaxial plating and/or ridge: (0) from center of ray; (1) from C radial/first primibrachial.
65. Approximate number of posterior interray plates: (0) one to four; (1) five to twelve; (2) more than twelve.
66. Primaxil location: (0) 1st primibrachial; (1) 2nd primibrachial; (2) 3rd primibrachial; (3) 4th primibrachial or higher.
67. Median ray ridges: (0) absent; (1) present.
68. Fixed first primibrachial shape: (0) 4-sided; (1) 5-sided; (2) 6-sided; (3) 8-sided.

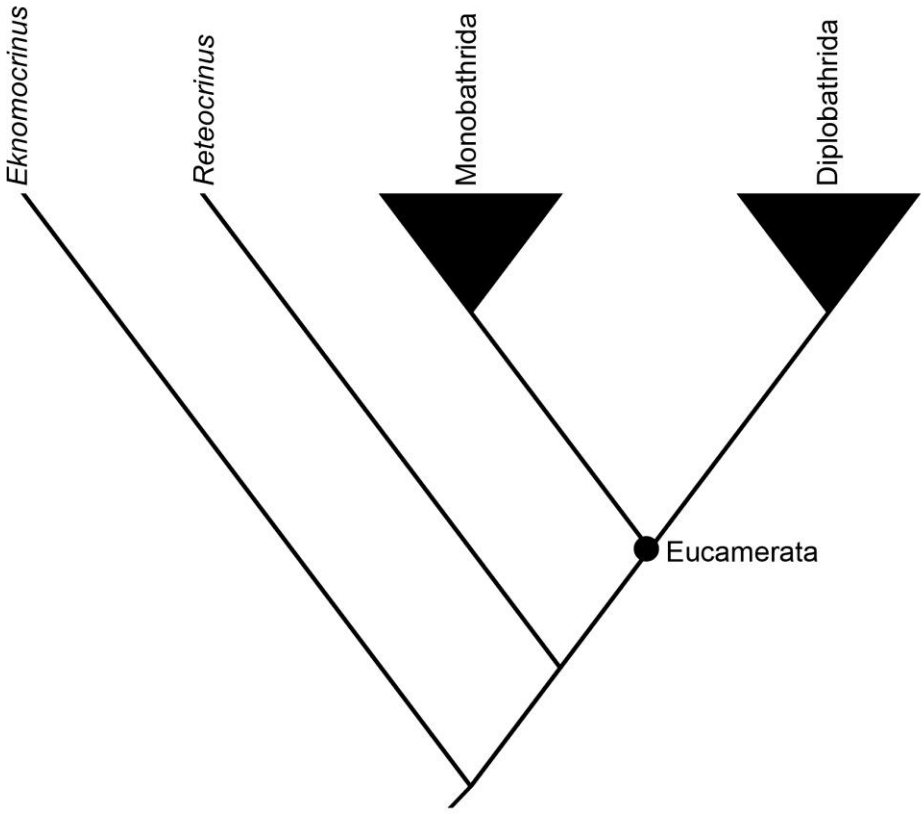
69. Fixed first primibrachial dimensions: (0) width>height; (1) height≈width; (2) height>width.
70. Maximum number of primibrachials: (0) one; (1) two; (2) three; (3) five or more
71. Maximum number of secundibrachials: (0) two; (1) three or more.
72. Symmetric branching in fixed brachials: (0) absent; (1) present.
73. Fixed pinnules: (0) absent; (1) present.
74. Fixed intersecundibrachials (between half rays): (0) absent; (1) present.
75. Fixed intertertibrachials (between quarter rays): (0) absent; (1) present.
76. Fixed interquartibrachials (between eighth rays): (0) absent; (1) present.
77. Arm openings into the calyx: (0) five; (1) ten; (2) fifteen; (3) twenty; (4) forty; (5) thirty.
78. Free arm openings grouped: (0) absent, arms not grouped; (1) present, arms grouped.
79. Arm habit: (0) erect; (1) pendant.
80. Free arm branching: (0) absent; (1) present.
81. Free arm branching type: (0) isotomous/poorly isotomous; (1) asymmetrical heterotomous; (2) endotomous; (3) exotomous; (4) holotomous.
82. Maximum number of free arm bifurcations: (0) one (1) two (2) three; (3) four or more.
83. Maximum number of total brachial bifurcations (fixed and free combined): (0) none; (1) one; (2) two; (3) three; (4) four; (5) five; (6) six; (7) ≥ seven.
84. Ramules: (0) absent; (1) present.
85. Pinnulation: (0) apinnulate; (1) pinnulate.
86. Pinnulation type: (0) regular (one pinnule per brachial); (1) hyperpinnulate (two pinnules per brachial).
87. Proximal pinnules enlarged: (0) absent; (1) present.
88. Proximal free arm brachials: (0) uniserial; (1) biserial.
89. Mature arm brachials: (0) uniserial; (1) biserial.
90. Mature brachial type, if uniserial: (0) rectilinear uniserial; (1) weakly to moderately cuneate uniserial; (2) strongly cuneate uniserial.
91. Mature brachial type, if biserial: (0) wedge biserial; (1) round biserial; (2) flat chisel biserial.
92. Differentiation of ambulacrals and interambulacrals: (0) absent; (1) present.
93. Ambulacral plates swollen: (0) absent; (1) present.
94. Interambulacral areas depressed: (0) absent; (1) present.
95. Interambulacral plate size relative to other tegmen plates): (0) smaller than other plates; (1) equal to other plates; (2) larger than other plates.
96. Number of interambulacrals: (0) few in each interray (up to ~10); (1) many in each interray (>10).
97. Peristomial cover plates differentiated: (0) absent; (1) present.
98. Tegmen height/width: (0) flat; (1) very low (<0.2); (2) low (0.2 to 0.4); (3) medium (0.4 to 0.75); (4) high (0.75 to 1.25); (5) very high (1.25 to 2.0).
99. Tegmen shape profile: (0) straight sides; (1) convex sides, widest at base if tegmen; (2) convex sides, widest above top of tegmen; (3) concave sides.
100. Tegmen height in relation to calyx: (0) lower than calyx; (1) tegmen approximately as high as calyx; (2) higher than calyx.
101. Tegmen outline in top view: (0) circular; (1) pentagonal; (2) lobate.
102. Tegmen plate sculpturing, including anal tube: (0) smooth; (1) nodose; (2) granulose; (3) ridges; (4) stellate ridges.
103. Approximate number of tegmen plates: (0) five; (1) 11 to 50; (2) >50.
104. Tegmen plates gradational in size from abaxial margin to center: (0) absent; (1) present.

105. Tegmen spines: (0) absent; (1) present.
106. Anus position: (0) Tegmen top, central; (1) tegmen top, eccentric; (2) calyx side
107. Anal tube: (0) absent; (1) present.
108. Anal tube height: (0) shorter than tegmen radius; (1) higher than tegmen radius but shorter than height of arms; (2) higher than height of arms; (3) short, raised bump.
109. Anal tube spines: (0) absent; (1) present.
110. Tubular tegmen extensions: (0) absent; (1) present.
111. Proxistele construction: (0) holomeric; (1) pentameric.
112. Mesistele construction: (0) holomeric; (1) pentameric.
113. Dististele construction: (0) holomeric; (1) pentameric.
114. Proxistele heteromorphic: (0) absent; (1) present
115. Mesistele heteromorphic: (0) absent; (1) present
116. Dististele heteromorphic: (0) absent; (1) present
117. Priminternodals: (0) absent; (1) present.
118. Secundinternodals: (0) absent; (1) present.
119. Tertinternodals: (0) absent; (1) present.
120. Columnal shape in proxistele columnals: (0) circular; (1) pentalobate; (2) pentagonal.
121. Columnal shape in mesistele columnals: (0) circular; (1) pentalobate; (2) pentagonal.
122. Columnal shape in dististele columnals: (0) circular; (1) pentalobate; (2) pentagonal.
123. Columnal height:width in proxistele: (0) discoidal (height:width < 0.5); (1) elongate (height:width > 0.5)
124. Columnal height:width in mesistele: (0) discoidal (height:width < 0.5); (1) elongate (height:width > 0.5)
125. Columnal height:width in dististele: (0) discoidal (height:width < 0.5); (1) elongate (height:width > 0.5)
126. Lumen shape in proxistele: (0) circular; (1) pentalobate; (2) pentagonal; (3) pentastellate
127. Lumen shape in mesistele: (0) circular; (1) pentalobate; (2) pentagonal; (3) pentastellate
128. Lumen shape in dististele: (0) circular; (1) pentalobate; (2) pentagonal; (3) pentastellate
129. Columnal articulation type: (0) symplexy, radial; (1) symplexy in petals (perpendicular to sides).
130. Areola: (0) absent; (1) present.
131. Branching on column proxistele: (0) absent; (1) cirri.
132. Branching on column mesistele: (0) absent; (1) cirri.
133. Branching on column dististele: (0) absent; (1) cirri.
134. Holdfast: (0) absent; (1) terminal rhizoids; (2) terminal cirri; (3) cemented; (4) coil; (5) plated.
135. Pores at plate sutures: (0) absent; (1) present.

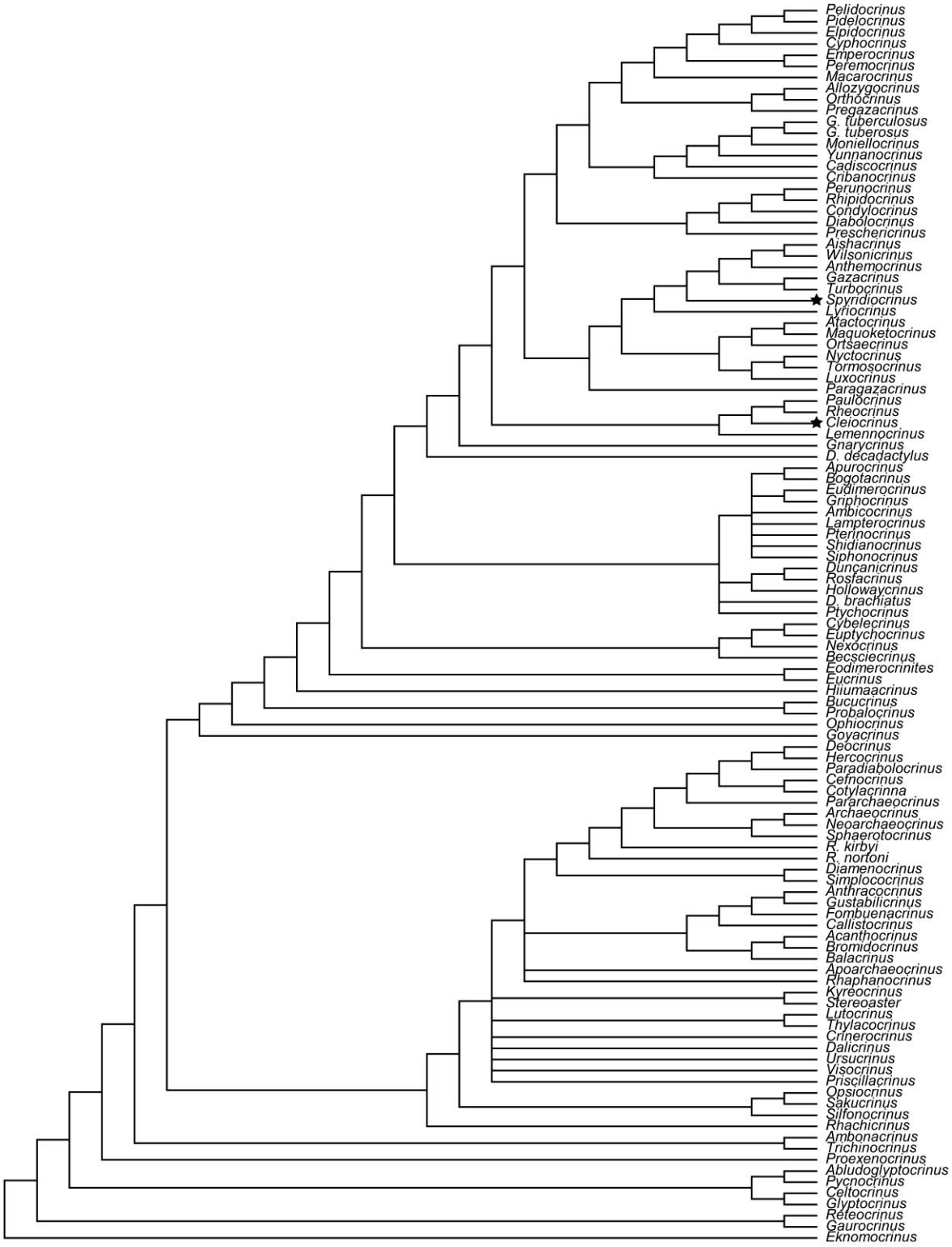
Supplemental Table 3. Morphological characters shared among ≥75% of genera within major groups recovered in the phylogenetic analysis. Characters that were unknown for ≥50% of genera within a group and characters found in high proportions across all groups are not shown. Clade designations correspond to those indicated in Figure 2.

Character number	Character	Clade A	Clade B1	Clade B2	Dimerocrinitoid Grade
1	Symmetry	-	Bilateral	-	Bilateral
3	Calyx width	-	-	Widest at top	Widest at top
7	Plate sculpturing	-	Smooth	Smooth	Smooth
12	Calyx lobation	Absent	-	-	-
14	Calyx sutures	-	Impressed	-	-
20	Basals part of basal concavity	Yes	-	Yes	No
25	Basal/interray contact	All interrays	All interrays	All interrays	CD interray only
26	CD basal differentiated from other basals	No	No	No	Yes
27	Radial circlet interruption	All interrays	All interrays	All interrays	CD interray only
29	Radial plate dimensions	-	Equant	Wider than high	Wider than high
34	Relative size of radials and basals	-	-	-	Radials > basals
35	Radials largest plate in calyx	-	-	-	Yes
40	Interray profile	-	-	Narrowing distally	-
47	Interrays depressed	Yes	Yes	Yes	-
58	CD interray differentiated	-	Yes	Yes	-
60	CD interray width compared to regular interrays	-	Same width	Same width	-
65	Number of posterior plates	>12	-	-	-
67	Median ray ridges	-	-	-	Absent
71	Maximum number of secundibrachials	-	-	≥3	≥3
77	Arm openings	-	-	10	-
80	Free arm branching	-	Unbranched	-	-
89	Mature arms	-	Biserial	Uniserial	-
126	Lumen shape	-	Pentalobate	-	-

Supplemental Figures



Supplemental Figure 1. Representation of constraint tree used in phylogenetic analyses of diplobathrids. Structure of the constraint tree was based on the results of Cole (2017). *Eknomocrinus* was constrained as the outgroup, *Reteocrinus* was constrained as sister to Eucamerata, and established members of Monobathrida and Diplobathrida were constrained to their respective clades. *Rosfacrinus* and *Gaurocrinus* were not included in the constraint tree so their positions would be free to vary in the analyses.



Supplemental Figure 2. Strict consensus of 41 MPT's recovered from parsimony analysis with *Cleiocrinus* included and backbone constraint imposed. Position of *Cleiocrinus* and *Spyridocrinus* (denoted by stars at terminal tips) does not support Zygodiplobathrina as an evolutionarily meaningful group. *R. = Rhodocrinites*, *D. = Dimerocrinites*, *G. = Gilbertsocrinus*.