
Supplementary information

A crown-group cnidarian from the Ediacaran of Charnwood Forest, UK

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A crown-group cnidarian from the Ediacaran of Charnwood Forest, UK.

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Included in this document:

Supplementary Discussion| Word file including a history of Ediacaran and Cambrian cnidarians and methods and character information on the morphospace and phylogenetic analyses presented in the main text.

Not Included in this document:

Extended data Figure 1| Unconstrained topologies presented in full. (A) Excluding the fossil taxa *Namacalathus* and *Eolympia*, *Antipathes* and those taxa that possess uninformative character states after safe taxonomic reduction (B) including all taxa. *Auroralumina* is recovered as a cnidarian in both trees. Fossil cnidarians are shown in bold and the position of *Auroralumina* is highlighted with a silhouette. Scale bar for branch lengths is in units of expected number of substitutions per site.

Extended data Figure 2| Constrained topologies. (A) Living cnidarian inter-relationships constrained against recent molecular phylogenies. B) ‘Ctenosis’ (ctenophores as sister to all other animals) constrained. All fossils were allowed to fully explore treespace under both set of constraints. *Auroralumina* is recovered as a cnidarian in both cases. Fossil cnidarians are shown in bold and the position of *Auroralumina* highlighted with a silhouette. Scale bar for branch lengths is in units of expected number of substitutions per site.

Extended data Figure 3| Maximum polyp width plotted for extant cnidarian Classes and fossil groups. *Auroralumina* has a much larger polyp width than any other sampled medusozoan. Maximum conulariid polyp width is also larger than any sampled living medusozoan. Source data available with manuscript.

Supplementary data file 1| Nexus file containing morphological phylogenetic dataset (Supplementary data file 1.nex)

Supplementary data file 2| CSV file with Tube morphospace dataset & polyp size data (Supplementary data file 2.csv)

Supplementary data file 3| R script used to analyse tube morphospace (Supplementary data file 3.r)

Supplementary discussion – other Ediacaran potential cnidarians:

Ediacaran frondose fossils - e.g. the rangeomorphs - were historically considered to be related to living sea pens, while isolated holdfast structures (e.g. *Aspidella*, *Cyclomedusa*) were sometimes interpreted as medusae (e.g.¹). These claims fell out of favour as more information about the growth and anatomy of these fossils came to light², but some recent work has suggested once again that rangeomorphs may belong to the total-group Cnidaria on the basis of their functional anatomy³. However, cnidarian - or even crown-group eumetazoan - characters (e.g. muscles, digestive cavities) have not been identified in rangeomorphs, with further developmental data from rangeomorphs suggesting they were not able to gastrulate as per crown-group eumetazoans⁴, and so are unlikely to represent cnidarian fossils.

Trace fossils from ~565-560 million year old strata have been interpreted to be of actinian/cnidarian grade^{5,6} and remain credible evidence for cnidarian-grade organisms. While recent work showing that abiogenic processes may generate similar surface traces casts doubt on the veracity of some of these claims⁷, the vertical traces remain uncontested and so we consider them reasonable evidence for cnidarian-grade organisms at this time. Like the majority of trace fossil evidence, however, these fossils cannot be placed confidently in a phylogeny or be used to inform character-state evolution. A recent paper suggested a polypoid ancestor for ctenophores⁸, increasing the number of possible trace makers for ichnofossils whose morphology is consistent with a polypoid tracemaker.

*Lantianella*⁹ is described from the Ediacaran-aged Member II of the Lantian Formation, China, in strata older than the Shuram Excursion⁹, and consists of a conical body with longitudinal filaments/ribs, with or without transverse banding and showing a crown of unbranched 'tentacle'-like structures. Similarity between *Lantianella* and another fossil, *Flabellophyton*, which has previously been interpreted as an alga¹⁰ on the basis of longitudinal filaments, has led some authors to suggest that *Flabellophyton* may represent a taphomorph of *Lantianella*, which does not preserve tentaculate features. An alternative explanation of it representing an earlier ontogenetic stage of *Lantianella*, perhaps with retracted tentacles^{9,11}, appears unlikely because the margins of the tentacles are continuous with the cone and do not emanate from within the cone as one might expect for feeding tentacles. Wan and colleagues⁹ describe phylogenetically diverse algal taxa which may possess a crown of blades, providing another explanation for such an anatomy, though they were not able to exclude a cnidarian affinity. Van Iten *et al.*¹² interpreted one specimen of *Lantianella* as a possible

conulariid on the basis of what was interpreted as a steeply pyramidal periderm with sub-triangular lappets. However, these structures haven't been observed in other specimens of *Lantianella*⁹, which is variable in overall form. Given this uncertainty and lack of diagnostic characters, we do not include *Lantianella* in our analyses nor do we consider it a likely candidate for an Ediacaran cnidarian body fossil.

Two additional Ediacaran-age fossils have drawn comparison to conulariids: *Vendoconularia*¹³ and *Paraconularia*¹⁴. *Vendoconularia* has recently been proposed to belong to the Family Protechiuridae¹⁵, including two other late Ediacaran genera: *Protechiurus* and *Vendoglossus*, with supposed affinities to the coronate scyphozoans via the conulariids and the anabartiids. However, *Protechiurus* tapers at both ends, which would be incompatible with a cnidarian affinity, and casts doubt on the affinity of *Vendoconularia*. *Paraconularia* from the Tamengo Formation is described as a conulariid, with a tetradial, elaborately ornamented tapering periderm, but it is only known - as with *Corumbella* - from close to the Ediacaran-Cambrian boundary and is therefore substantially younger (~15Ma) than *Auroralumina*.

Supplementary discussion - Morphospace and phylogenetic methods and information:

Our morphospace analysis includes 54 taxa 52 characters. Some characters are taken from either the datamatrix of Selly *et al.* 2020¹⁶ or Park *et al.* 2021¹⁷, though note that we split multistate characters into multiple discrete characters. Characters are described below and primary references from which morphological data was acquired are listed in a table. Unless otherwise specified, type species were used.

Taxon name	Key references
<i>Cloudina carinata</i>	Cortijo <i>et al.</i> 2010 ¹⁸ Park <i>et al.</i> 2021 ¹⁷
<i>Cloudina hartmanae</i>	Germes 1972 ¹⁹ Park <i>et al.</i> 2021 ¹⁷
<i>Cloudina riemkaea</i>	Germes 1972 ¹⁹ Park <i>et al.</i> 2021 ¹⁷
<i>Cloudina lucianoii</i>	Adorno <i>et al.</i> 2017 ²⁰ Park <i>et al.</i> 2021 ¹⁷

<i>Conotubus</i>	Selly <i>et al.</i> 2020 ¹⁶ Cai <i>et al.</i> 2011 ²¹
<i>Costatubus</i>	Selly <i>et al.</i> 2020 ¹⁶
<i>Feiyanella</i>	Selly <i>et al.</i> 2020 ¹⁶ Han <i>et al.</i> 2017 ²²
<i>Multiconotubus</i>	Cai <i>et al.</i> 2017 ²³ Min <i>et al.</i> 2019 ²⁴ Selly <i>et al.</i> 2020 ¹⁶
<i>Rajatubulus</i>	Yang <i>et al.</i> 2016 ²⁵ Selly <i>et al.</i> 2020 ¹⁶
<i>Saarina hagadorni</i>	Selly <i>et al.</i> 2020 ¹⁶
<i>Annulatubus</i>	Carbone <i>et al.</i> 2015 ²⁶ Selly <i>et al.</i> 2020 ¹⁶
<i>Corumbella</i>	Walde <i>et al.</i> 2019 ²⁷
<i>Funisia</i>	Droser <i>et al.</i> 2008 ²⁸ Surprenant <i>et al.</i> 2020 ²⁹
<i>Gaojiashania</i>	Selly <i>et al.</i> 2020 ¹⁶ Cai <i>et al.</i> 2013 ³⁰
<i>Rugatotheca</i>	Selly <i>et al.</i> 2020 ¹⁶ Yang <i>et al.</i> 2016 ²⁵
<i>Sabellidites</i>	Selly <i>et al.</i> 2020 ¹⁶ Ebbestad <i>et al.</i> 2021 ³¹
<i>Sekwitubus</i>	Carbone <i>et al.</i> 2015 ²⁶ Selly <i>et al.</i> 2020 ¹⁶
<i>Shaanxilithes</i>	Selly <i>et al.</i> 2020 ¹⁶ Wang <i>et al.</i> 2021 ³²
<i>Sinotubulites baimatuoensis</i>	Cai <i>et al.</i> 2015 ³³
<i>Sinotubulites triangularis</i>	Cai <i>et al.</i> 2015 ³³
<i>Sinotubulites pentacarinalis</i>	Cai <i>et al.</i> 2015 ³³
<i>Sinotubulites hexagonus</i>	Cai <i>et al.</i> 2015 ³³
<i>Somatohelix</i>	Sappenfield <i>et al.</i> 2011 ³⁴ Selly <i>et al.</i> 2020 ¹⁶
<i>Vendoconularia</i>	Ivantsov and Fedonkin 2002 ¹³

<i>Wutubus</i>	Chen <i>et al.</i> 2014 ³⁵ Selly <i>et al.</i> 2020 ¹⁶
<i>Olivoooides</i>	Dong <i>et al.</i> 2013 ³⁶
<i>Arthrochites</i>	Conway Morris and Chen 1992 ³⁷
<i>Septuconularia</i>	Guo <i>et al.</i> 2020 ³⁸
<i>Pseudoooides</i>	Duan <i>et al.</i> 2017 ³⁹
<i>Quadrapyrgites</i>	Liu <i>et al.</i> 2014 ⁴⁰
<i>Conulariella</i>	Leme <i>et al.</i> 2008 ⁴¹ Van Iten <i>et al.</i> 2013 ⁴²
<i>Paraconularia</i> (Tamengo Formation)	Van Iten <i>et al.</i> 2014 ⁴³
<i>Baccaconularia</i>	Hughes <i>et al.</i> 2000 ⁴⁴
<i>Emeiconularia</i>	Yunhuan <i>et al.</i> 2005 ⁴⁵ Han <i>et al.</i> 2018 ⁴⁶
<i>Carinachites</i>	Conway Morris and Chen 1992 ³⁷ Han <i>et al.</i> 2018 ⁴⁶
<i>Pentaconularia</i>	Liu <i>et al.</i> 2011 ⁴⁷ Han <i>et al.</i> 2018 ⁴⁶
<i>Sphenothallus taijiangensis</i>	Dzik <i>et al.</i> 2016 ⁴⁸ Zhu <i>et al.</i> 2000 ⁴⁹
<i>Byronia</i>	Zhu <i>et al.</i> 2000 ⁴⁹
<i>Anabarites tripartitus</i>	Junyuan <i>et al.</i> 2005 ⁵⁰ Shao <i>et al.</i> 2015 ⁵¹
<i>Anabarites sexalox</i>	Junyuan <i>et al.</i> 2005 ⁵⁰ Shao <i>et al.</i> 2015 ⁵¹
<i>Hyolithellus</i>	Skovsted and Peel 2011 ⁵²
<i>Cambrocotonus koori</i>	Peel 2017 ⁵³ Park <i>et al.</i> 2021 ¹⁷
<i>Cambroctoconus krygyzstanicus</i>	Geyer <i>et al.</i> 2014 ⁵⁴ Park <i>et al.</i> 2021 ¹⁷
<i>Cambroctoconus coreaensis</i>	Park <i>et al.</i> 2016 ⁵⁵ Park <i>et al.</i> 2021 ¹⁷
<i>Cambroctoconus orientalis</i>	Park <i>et al.</i> 2011 ⁵⁶ Park <i>et al.</i> 2021 ¹⁷

<i>Lipopora lissa</i>	Park <i>et al.</i> 2021 ¹⁷
<i>Lipopora daseia</i>	Park <i>et al.</i> 2021 ¹⁷
<i>Tretocylichne</i>	Park <i>et al.</i> 2021 ¹⁷
<i>Dasyconus</i>	Korde 1964 ⁵⁷ Zhuravlev, Debrenne and Lefuste 1993 ⁵⁸
<i>Hydroconus</i>	Korde 1964 ⁵⁷ Zhuravlev, Debrenne and Lefuste 1993 ⁵⁸
<i>Cothonion</i>	Jell and Jell 1976 ⁵⁹ Peel 2011 ⁶⁰
<i>Moorowipora</i>	Fuller and Jenkins 2007 ⁶¹ Scrutton 1997 ⁶²
<i>Flindersipora</i>	Fuller and Jenkins 2007 ⁶¹ Scrutton 1997 ⁶²

Character list

1. Biomineral. Whether a tube is biomineralised or not. *Cloudina*, *Feiyanella*, *Multiconotubus*, *Rajatubulus*, *Rugatotheca*, *Sinotubulites*, the conulariids *Conulariella* and *Baccaconularia*, all carinachitids, hexangulaconulariids, *Byronia*, *Sphenothallus* *Anabarites*, *Hyolithellus*, *Cambroctoconus*, *Lipopora*, *Tretocylichne*, hydroconozoans, *Cothonion* and tabulconids were all scored as present for biomineral skeletons. *Conotubus*, *Costatubus*, *Saarina*, *Gaojiashania*, *Sabellidites*, *Shaanxilithes*, *Somatohelix*, *Vendoconularia*, *Paraconularia* (from the Tamengo Formation) and *Auroralumina* were scored as absent. All other taxa were unknown.

0 absent

1 present

2. Mineral type. Of the taxa scored present for biomineralisation, the type of mineral was not known in *Multiconotubus*, *Feiyanella* and *Rajatubulus*. Data on mineral type was harvested from key references and from⁶³.

0 phosphate

1 calcite

2 aragonite

3. Adapical end cylindrical. The adapical end of all species of *Cloudina* apart from *C. carinata* was scored as cylindrical, *Conotubus*, *Costatubus*, *Feiyanella*, *Multiconotubus*, *Rajatubulus*, *Saarina*, *Annulatubus*, *Corumbella*, *Funisia*, *Gaojianshani*, *Rugantotheca*, *Sabellidites*, *Sekwitubulus*, *Sinotubulites baimatuoensis*, *Wutubus*, *Byronia*, *Hyolithellus*, *Dasyconus*, *Hydroconus*, *Cothonion*, *Moorowipora* and *Flindersipora* were all scored as having cylindrical adapical ends. All other taxa were scored as absent.

0 absent

1 present

4. Adapical end polyhedral. The adapical end of *Cloudina carinata* is polyhedral, as is the adapical end of olivoids, carinachitids, hexangulaconulariids, conulariids, anabaritids, *Auroralumina* and the tabuloconids. All other taxa were scored as absent.

0 absent

1 present

5. Adapical end flattened. *Shaanxilithes* and *Sphenothallus* are the only taxa scored as present for this character, all others are absent. *Shaanxilithes* was scored from Selly *et al.* 2020 where they term the morphology ‘ribbon-like’.

0 absent

1 present

6. Biradial tube. *Shaanxilithes*, *Arthrochites*, *Septuconularia*, *Pseudoooides*, *Sphenothallus* and *Conulariella* were scored as being biradial. *Auroralumina* was scored as ?.

0 absent

1 present

7. Tetraradial tube. *Quadrropyrgites*, *Paraconularia* (from the Tamengo Formation), *Baccaconularia*. *Auroralumina* was scored as ‘?’ and all other taxa were scored as absent.

0 absent

1 present

8. Triradial tube. *Sinotubulites triangularis*, *Vendoconularia*, *Emeiconularia* and *Anabarites tripartitus* are both scored as having triradial symmetry, but all other taxa are scored as absent.

0 absent

1 present

9. Pentaradial tube. *Sinotubulites pentacarinalis*, *Olivoooides* and *Pentaconularia* are scored as having pentaradial symmetry. All other taxa are scored as absent.

0 absent

1 present

10. Hexaradial tube. *Sinotubulites hexagonus* and *Anabarites sexalox* are both hexaradial.

0 absent

1 present

11. Octoradial tube. *Cloudina carinata* is scored as octoradial, all species of *Cambroctoconus*, *Lipopora* and *Tretocylichne* were also scored as having octoradial symmetry, following¹⁷. *Cloudina luciano* is ‘?’.

0 absent

1 present

12. Tube tapering. Does the tube decrease in width along its length. All species of *Cloudina*, *Rajatubulus*, *Annulatubus*, *Corumbella*, *Sekwitubus*, *Vendoconularia*, *Wutubus*, olivoooids, hexangulaconulariids, conulariids, anabaritiids, *Byronia*, *Sphenothallus*, *Hyolithellus*, hydroconozaans and *Cothonion* are all scored as showing a tapering tube. All other taxa are scored as absent.

0 absent

1 present

13. Tube taper steep. Some tubes have a noticeably steeper incline and were scored as present for a steep taper. These include the hexangulaconulariids, conulariids and *Cothonion*. All other taxa that were scored as possessing a tapering tube were absent for this character.

0 absent

1 present

14. Funnel in funnel structure. Describing the nested tubular anatomy of a number of Ediacaran-Cambrian tubes. All cloudinomorphs (*Cloudina*, *Conotubus*, *Costatubus*, *Feiyanella*,

Multiconotubus, *Rajatubulus* and *Saarina*) were scored as present for this character, as were *Sinotubulites*, *Cambroctoconus orientalis* and *Lipopora*. *Dasyconus* and *Hydroconus* are scored as '?' because it is not possible to assess whether they show a funnel-in-funnel structure from the published figures. All other taxa were considered absent and were therefore scored as inapplicable for the following four characters.

0 absent

1 present

15. Funnels are true funnels. *Cloudina*, *Conotubus*, *Rajatubulus* and *Saarina* have funnels. Funnels are shorter than cones, following¹⁶

0 absent

1 present

16. Funnels are barrels. *Costatubus*, *Sinotubulites* and *Lipopora* have barrels.

0 absent

1 present

17. Funnels are cones. *Feiyanella*, *Multiconotubus* and *Cambroctoconus orientalis* have cones. Cones are longer than funnels, following¹⁶.

0 absent

1 present

18. Degree of overlapping funnel-in-funnel structure. *Cloudina hartmanae* and *Cloudina luciano* both overlap more than half an element, as do *Feiyanella* and *Multiconotubus*. All other funnel-in-funnel taxa scored as absent. This character was adapted from Park *et al.* 2021¹⁷.

0 below half of element

1 over half of element

19. Transverse ridges across majority of exterior. *Annulatubus*, *Corumbella*, *Funisia*, *Gaojiashania*, *Rugatotheca*, *Sabellidites*, *Sekwitubulus*, *Shaanxilithes*, *Sinotubulites*, *Somatohelix*, *Vendoconularia*, *Wutubus*, olivoids, hexangulaconulariids, conulariids, carinachitids, *Byronia*, *Sphenothallus*, *Hyolithellus*, *Lipopora* are scored as present. Hydroconozoans are scored as '?' because it is not clear whether they exhibit true ridges or

the ridges are an expression of funnel-in-funnel architecture. The following two characters are contingent on the presence of this character.

0 absent

1 present

20. Ridges make up entire external tube morphology or not. Ridges may either account for the entire tube (e.g. *Wutubus*) or may be present overtop a tube structure (e.g. conulariids). Bulbous ridges are found in *Annulatubus*, *Funisia*, *Sekwitubulus*, *Somatohelix*, *Wutubus*, *Olivoooides* and *Quadrapyrgites*. All other taxa show non-bulbous ridges. If ridges make up entire tube then character 21 is inapplicable.

0 entire tube

1 overlain

21. Continuation of transverse ornament across entire circumference. Some taxa show breaks in the transverse ornament and this may be either associated with a longitudinal structure (e.g. sulcus) or not. Taxa scored as showing continuation of the transverse ornament are: *Corumbella*, *Gaojiashania*, *Rugatotheca*, *Sabellidites*, *Shaanxilithes*, *Sinotubulites*, *Pseudoooides*, *Paraconularia* (based on the genus), *Byronia*, *Sphenothallus*, *Hyolithellus*, *Lipopora*. All other taxa are scored as absent apart from *Baccaconularia* where the available images are not sufficient to be able to say with certainty, so we leave it as ‘?’.

0 absent

1 present

22. Tubercles on exterior. Tubercles may be any shape and associated (or not) with any structure. *Pseudoooides*, *Quadrapyrgites*, *Paraconularia* and *Baccaconularia* are scored as present. All other taxa are considered absent and so are scored as inapplicable for the following two characters.

0 absent

1 present

23. Tubercles associated with transverse ribs. Only *Paraconularia* and *Baccaconularia* are scored present for this character.

0 absent

1 present

24. Tubercles are thorn-like projections. Only *Quadrapyrgites* displays tubercles as thorny projections.

0 absent

1 present

25. Longitudinal ornament. This character does not include sulci. *Olivoooides*, *Arthrochites*, *Quadrapyrgites*, carinachitids and *Byronia* are scored as present. All other taxa are absent for this character.

0 absent

1 present

26. Closed terminal apex. For taxa with an incomplete apex - *Auroralumina* and the carinachitids – this was left as ‘?’, and so too for taxa where it is not possible to assess the apex of individual tubes from published figures (*Morrowipora* and *Flindersipora*). *Cloudina carinata*, *Cloudina riemkaea*, *Cloudina lucianoi*, *Conotubus*, *Feiyanella*, *Multiconotubus*, *Saarina*, *Corumbella*, *Funisia*, *Sekwitubulus*, *Somatohelix*, *Vendoconularia*, *Wutubus*, olivoooids, hexangulaconulariids, conulariids, *Sphenothallus*, *Byronia*, *Anabarites*, *Cambroctoconus*, *Lipopora*, *Tetroclichne*, *Dasyconus* and *Cothonion* were scored as present for this character and all others were scored absent. The following two characters are contingent on the presence of a closed apex.

0 absent

1 present

27. Apical boss with different ornament. The difference in ornament may be either in the presence of dimples or the presence of tighter transverse ornament. Olivoooids, hexangulaconulariids and *Conulariella* are scored as present.

0 absent

1 present

28. Holdfast (attachment disc). *Cloudina hartmanae*, *Funisia*, *Sekwitubulus*, *Sphenothallus*, *Cambroctoconus*, *Lipopora*, *Tetroclichne*, *Dasyconus* and *Cothonion* are scored as present, while the remaining three species of *Cloudina*, *Costatubus*, *Rajatubulus*, *Saarina*, all

conulariids, carinachitids and *Auroralumina* are scored as unknown. All other taxa are scored as absent.

0 absent

1 present

29. Oral lobes at aperture. This is scored as present in *Olivoides*, *Quadrupyrigites* and the carinachitids. It is absent in all other taxa.

0 absent

1 present

30. Operculum. This is present in *Cothonion* and absent in all other taxa.

0 absent

1 present

31. Tube separated into distinct zones. This may be at any height along the tube and is demonstrated by rapid transitions in the width of the tube. It is present in *Auroralumina* and the hydroconozoans, but absent in all other taxa.

0 absent

1 present

32. Tubes have faces. Distinct faces are present in *Cloudina carinata*, *Sinotubulites triangularis*, *Sinotubulites pentacarinalis*, *Sinotubulites hexagonus*, *Vendoconularia*, olivoids, carinachitids, hexangulaconulariids, conulariids, *Sphenothallus*, *Auroralumina*, *Anabarites*, *Cambroctoconus*, *Lipopora* and *Tretocylichne*, but are absent in all other taxa.

0 absent

1 present

33. Tubes have external midline(s). Midline(s) are present in the hexangulaconulariids and *Paraconularia*, but are absent in all other taxa.

0 absent

1 present

34. Midlines between tubes. This is contingent on a colonial lifestyle. It is scored as present in *Moorowipora* and *Flindersipora*, absent in *Cloudina carinata*, *Cloudina hartmanae*, *Cloudina riemkaea*, *Feiyanella*, *Funisia*, *Sphenothallus*, *Auroralumina*, *Cambroctoconus*,

Lipopora lissa, *Tretocylichne* are all scored as absent as they either are clearly colonial or exhibit branching. All other taxa are scored as inapplicable.

0 absent

1 present

35. Tubes have sulci. As sulci impart a polyhedral symmetry on the tube, taxa which lack polyhedral symmetry - *Sinotubulites baimatuoensis* and the hydroconozoans – are scored as inapplicable. *Conulariella*, *Paraconularia*, the carinachitids, *Auroralumina*, *Anabarites* and *Cothonion* are scored as present and all others absent.

0 absent

1 present

36. Tubes are approximately straight. Many tubes exhibit some curvature (e.g. *Anabarites*), but some are markedly bent or twisted (e.g. *Somatohelix*). This is the morphology we intend to pick out with this character. *Cloudina hartmanae*, *Sinotubulites*, *Vendoconularia*, *Wutubus*, olovoids, hxangulaconulariids, conulariids, carinachitids, *Auroralumina*, *Byronia*, *Sphenothallus*, *Hyolithellus*, *Lipopora*, hydroconozoans, *Cothonion*, *Moorowipora* and *Flindersipora* are all scored as showing straight tubes and all others as absent for this character.

0 absent

1 present

37. Branching observed. Branching has been observed in: *Cloudina*, *Feiyanella*, *Funisia*, *Sphenothallus*, *Auroralumina*, *Cambroctoconus krygystanics*, *Cambroctoconus coreaensis*, *Cambroctoconus orientalis*, *Lipopora lissa*, *Tretocylichne*, *Morrowipora* and *Flindersipora* but is absent in all other taxa.

0 absent

1 present

38. Ceroid growth. A type of colony formation with many tubes, each retaining their own tube wall. Tubes are packed together and so branching as observed in *Cloudina* or *Auroralumina* does not represent this growth form. This is scored as present in *Morrowipora* and *Flindersipora* only.

0 absent

1 present

39. Parricidal increase. Describing a form of colony growth which can only be scored in taxa which show branching. It is scored as present in *Moorowipora* and *Flindersipora* and absent in all other taxa.

0 absent

1 present

40. Di/Trichotomous branching. This is scored as present in *Cloudina carinata*, *Cloudina hartmanae*, *Cloudina riemkaea*, *Feiyanella*, *Funisia*, *Auroralumina*, *Lipopora lissa*, *Morrowipora* and *Flindersipora* and absent in all other branching taxa.

0 absent

1 present

t

41. Budding from outer surface of skeleton. This is scored as inapplicable in all taxa in which branching is not observed. *Sphenothallus*, *Cambroctoconus kyrgyzstanicus*, *Cambroctoconus coreaensis*, *Cambroctoconus orientalis*, *Lipopora lissa* and *Tretocylichne* are all scored as present and other taxa are scored as absent. *Cambroctoconus koori* is left '?', following Park *et al.* 2021¹⁷.

0 absent

1 present

42. Budding from inner surface of skeleton. This is not contingent on an outwardly branching anatomy because it may not result in an outwardly branched morphology. This is scored as present in *Cloudina lucianoi*, *Cambroctoconus kyrgyzstanicus*, *Cambroctoconus coreaensis* and *Cambroctoconus orientalis* and absent in other taxa. It is scored as unknown in taxa where the preservational style means the internal anatomy is not known: *Annulatubus*, *Funisia*, *Sekwitubulus*, *Somatohellix*, *Vendoconularia*, *Gaojiashania* and *Wutubus*. The hydroconozoans and *Auroralumina* are also scored as '?' because small specimen size means that the available material is not a reliable test and *Cambroctoconus koori* is left '?', following Park *et al.* 2021¹⁷.

0 absent

1 present

43. Internal septa. We use the term septa in the broadest sense, to mean invaginations from the tube which do not reach the other tube wall, but separate this from sulci which are folds in the wall. Olivoids, *Hyolithellus*, *Cambroctoconus*, *Lipopora*, *Tretocylichne*, hydroconozoans, *Cothonion*, *Flindersipora* and *Moorowipora* are scored as present, and all other taxa are absent except for *Auroralumina*, *Sphenothallus*, *Baccaconularia*, *Paraconularia*, *Conulariella*, hexangulaconulariids, *Wutubus*, *Sekwitubus*, *Gaojiashania*, *Funisia* and *Annulatubus*, which are scored as unknown because we do not have access to their internal anatomy. The following two characters are contingent on the presence of septa.

0 absent

1 present

44. Number of septa is 8 or multiple of 8. This is present in *Cambroctoconus koori*, *Cambroctoconus krygzstanicus*, *Cambroctoconus orientalis*, *Lipopora lissa* and *Tretocylichne* and absent in all other septate tubes. There are no consistent septal patterns in any other group of sampled tubes so we refrain from erecting further characters.

0 absent

1 present

45. Septa paired. This is present in olivoids, *Cambroctoconus krygzstanicus*, *Cambroctoconus orientalis* and *Tretocylichne*, but absent in all other septate tubes.

0 absent

1 present

46. Horizontal internal elements. This refers to features like tabulae and is scored as present in *Cambroctoconus krygzstanicus*, *Cambroctoconus orientalis*, *Moorowipora* and *Flindersipora*. It is scored as unknown – as per internal septa – in *Auroralumina*, *Sphenothallus*, *Baccaconularia*, *Paraconularia*, *Conulariella*, hexangulaconulariids, *Wutubus*, *Sekwitubus*, *Gaojiashania*, *Funisia* and *Annulatubus*. All other taxa are scored as absent.

0 absent

1 present

47. Smooth inner walls. This is scored as present in *Cloudina carinata*, *Cloudina riemkaea*, *Cloudina lucianoi*, *Conotubus*, *Costatubus*, *Multiconotubus*, *Saarina*, *Sabellidites*,

Shaanxilithes, *Sinotubulites* and *Anabarites*, carinachitids and unknown in the same taxa as per internal septa: *Auroralumina*, *Sphenothallus*, *Baccaconularia*, *Paraconularia*, *Conulariella*, hexangulaconulariids, *Wutubus*, *Sekwitubus*, *Gaojiashania*, *Funisia* and *Annulatubus*. All other taxa are scored as absent.

0 absent

1 present

48. Tubes multi-layered. This does not include overlapping funnel-in-funnel tubes. This is scored as present in *Feiyanella*, *Multiconotubus*, *Shaanxilithes*, *Sinotubulites* and *Dasyconus* and unknown in taxa preserved by cast and mould (*Funisia*, *Somatohelix* and *Auroralumina*), but absent in all other taxa.

0 absent

1 present

49. Perforations in the skeletal wall. This is scored as present in *Cambroctoconus*, *Lipopora*, *Tretocylichne*, *Hydroconus*, *Moorowipora* and *Flindersipora*. It is scored as unknown in *Dasyconus*, where only one specimen is known through thin section and absent in all other taxa. The next character is contingent on the presence of this character.

0 absent

1 present

50. Longitudinal canals opening to exterior. This is present in *Hydroconus* only and unknown in *Dasyconus*.

0 absent

1 present

Phylogenetic methods:

We conducted our analyses using Bayesian Inference, implemented in MrBayes 3.2.6, since probabilistic approaches are considered to provide more accurate results when analysing discrete morphological data^{64,65}. We followed the multistate coding strategy of Brazeau (2011)⁶⁶. Our matrix was based on Zhao *et al.* (2019⁸), which focuses on cnidarians and ctenophores. We have extended the taxon sample to include the extant cubozoan *Morbakka*⁶⁷ and the fossil taxa *Eoconularia*⁶⁸, *Conularia*⁶⁹, *Carinachites*⁴⁶ and *Auroralumina*. Although retained in our matrix, the taxa *Agalma*, *Keratoisidinae*, *Thaumactena*, *Trigoooides* and *Craseoa* were removed as they did not possess

informative character combinations, and *Antipathes* was removed because it collapsed the Anthozoan crown-group node. The fossil taxa *Eolympia* and *Namacalathus* were not included in the topology presented in main text Fig. 4 because they have been omitted from previous studies because of very large amounts of missing data and equivocal taxonomic status⁸.

Our presented topology is run without any topological constraints. However, as the inter-relationships of some of our recovered clades conflicts with recent molecular phylogenies^{70,71}, we conducted additional analyses where we constrained our tree topology to that of molecular studies. Additionally, to ensure our recovered topology was not the direct result of our recovery of a sister relationship between the Cnidaria and the Ctenophora, we conducted an analysis constraining ctenophores as the sister to all other animals (Ctenosis), as is recovered by some molecular phylogenies⁷². Topological constraints are presented below.

Topological constraints:

Partial constraints were used to allow all fossil taxa to wander.

Cnidarian inter-relationships following recent molecular phylogenies:

constraint node1 partial = Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes : Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node2 partial = Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia : Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae

Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node3 partial = Anthomastus Leptogorgia Virgularia : Nematostella Anemonia Aiptasia
Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus
Halicylustus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node4 partial = Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia
Corynactis Montastraea Porites Acropora Parazoanthus : Anthomastus Leptogorgia Virgularia
Halicylustus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node5 partial = Nematostella Anemonia Aiptasia Metridium Parazoanthus : Antipathes
Ceriantharia Corynactis Montastraea Porites Acropora Anthomastus Leptogorgia Virgularia
Halicylustus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida

Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node6 partial = Nematostella Anemonia Aiptasia Metridium : Parazoanthus Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Anthomastus Leptogorgia Virgularia Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node7 partial = Anemonia Aiptasia Metridium : Nematostella Parazoanthus Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Anthomastus Leptogorgia Virgularia Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node8 partial = Aiptasia Metridium : Anemonia Antipathes Nematostella Parazoanthus Ceriantharia Corynactis Montastraea Porites Acropora Anthomastus Leptogorgia Virgularia Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida

Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node9 partial = Corynactis Montastraea Porites Acropora Antipathes : Nematostella
Anemonia Aiptasia Metridium Ceriantharia Parazoanthus Anthomastus Leptogorgia Virgularia
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node10 partial = Montastraea Porites Acropora : Antipathes Corynactis Nematostella
Anemonia Aiptasia Metridium Ceriantharia Parazoanthus Anthomastus Leptogorgia Virgularia
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node11 partial = Porites Acropora : Nematostella Anemonia Aiptasia Metridium Antipathes
Ceriantharia Corynactis Montastraea Parazoanthus Anthomastus Leptogorgia Virgularia Haliclystus
Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia
Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa
Abylopsis Agalma Nanomia Aeginia Halitrephes Choanoflagellata Demospongiae Homoscleromorpha
Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida
Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia
Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata

Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node12 partial = Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes : Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node13 partial = Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma : Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node14 partial = Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma : Haliclystus Lucernaria Calvadosia Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node15 partial = Haliclystus Lucernaria Calvadosia : Alatina Chironex Morbakka Atolla
Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node16 partial = Lucernaria Calvadosia : Haliclystus Alatina Chironex Morbakka Atolla
Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node17 partial = Alatina Chironex Morbakka : Haliclystus Lucernaria Calvadosia Atolla
Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node18 partial = Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma :
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node19 partial = Atolla Stephanoscyphus Nausithoe : Aurelia Cassiopea Rhizostoma
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node20 partial = Aurelia Cassiopea Rhizostoma : Atolla Stephanoscyphus Nausithoe
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Hydra Candelabrum Hydractinia
Ectopleura Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node21 partial = Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes : Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node22 partial = Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia : Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node23 partial = Hydra Ectopleura Candelabrum : Clytia Obelia Physalia Craseoa
Abylopsis Agalma Nanomia Hydractinia Aeginia Halitrephes Haliclystus Lucernaria Calvadosia
Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma
Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites
Acropora Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node24 partial = Hydractinia Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia :
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node25 partial = Clytia Obelia Physalia Craseoa Abylopsis Agalma Nanomia : Hydractinia
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node26 partial = Physalia Craseoa Abylopsis Agalma Nanomia : Clytia Obelia Hydractinia
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node27 partial = Craseoa Abylopsis Agalma Nanomia : Physalia Clytia Obelia Hydractinia
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node28 partial = Craseoa Abylopsis : Agalma Nanomia Physalia Clytia Obelia Hydractinia
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta
Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

constraint node29 partial = Agalma Nanomia : Craseoa Abylopsis Physalia Clytia Obelia Hydractinia
Hydra Ectopleura Candelabrum Aeginia Halitrephes Haliclystus Lucernaria Calvadosia Alatina
Chironex Morbakka Atolla Stephanoscyphus Nausithoe Aurelia Cassiopea Rhizostoma Nematostella
Anemonia Aiptasia Metridium Antipathes Ceriantharia Corynactis Montastraea Porites Acropora
Parazoanthus Anthomastus Leptogorgia Virgularia Choanoflagellata Demospongiae
Homoscleromorpha Calcarea Hexactinellida Placozoa Euplokamis Mnemiopsis Beroida Platyctenida
Cestida Ganeshida Thalassocalycida Bryozoa Brachiopoda Phoronida Mollusca Annelida
Echinodermata Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta

Urochordata Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida
Gastrotricha Tardigrada Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes ;

Ctenosis (Ctenophore sister to all other animals):

constraint Ctenosis partial = Nematostella Anemonia Aiptasia Metridium Antipathes Ceriantharia
Corynactis Montastraea Porites Acropora Parazoanthus Anthomastus Leptogorgia Virgularia
Haliclystus Lucernaria Calvadosia Alatina Chironex Morbakka Atolla Stephanoscyphus Nausithoe
Aurelia Cassiopea Rhizostoma Hydra Candelabrum Hydractinia Ectopleura Clytia Obelia Physalia
Craseoa Abylopsis Agalma Nanomia Aeginia Halitrephes Demospongiae Homoscleromorpha
Calcarea Hexactinellida Placozoa Bryozoa Brachiopoda Phoronida Mollusca Annelida Echinodermata
Pterobranchia Chaetognatha Onychophora Arthropoda Nemertea Enteropneusta Urochordata
Cephalochordata Vertebrata Entoprocta Nematoda Nematomorpha Priapulida Gastrotricha Tardigrada
Kinorhyncha Loricifera Gnathifera Xenacoelomorpha Platyhelminthes : Choanoflagellata Euplokamis
Mnemiopsis Beroida Platyctenida Cestida Ganeshida Thalassocalycida;

Character list:

New characters or characters where we have changed the scoring strategy are indicated with an asterisk. Changes to previously existing characters might include corrected mistakes or changes in character contingencies.

1. Collar complex

0 - absent

1 - present

2. Multicellularity with extracellular matrix

0 - absent

1 - present

3. Septate junctions

0 - absent

1 - present

4. Tight junctions

0 - absent

1 - present

5. Gap junctions

0 - absent

1 - present

6. Adherens junctions

0 - absent

1 - present

7. Hemidesmosomes

0 - absent

1 - present

8. Epithelia* - Cell associations which line the exterior surface of an organism and are underlain by collagenous sheets. Sponges, while not typically possessing the sealing cell junctions found in the epithelia of other animals do possess cell junctions (characters 2-6) and so we score this character as being present in all animals.

0 - absent

1 - present

9. Differentiation of two epithelial layers* - This is present in all animals with a true epithelium except homoscleromorph sponges, which do not differentiate two epithelial layers⁷³.

0 - absent

1 - present

10. Basal laminae - We score this as present in absent in all sponges except homoscleromorphs⁷³.

All sponge Classes can possess epithelia underlain by collagenous sheets, but this is not true epithelia because they do not possess basal laminae. This is not the case in homoscleromorph sponges, which do possess epithelia with basal laminae, and so we consider them to possess a true epithelium.

0 - absent

1 - present

11. Aquiferous system with ostia and osculae* - A connected system of water channels found exclusively in sponges consisting of inhalent and exhalent openings, or ostia and osculae, respectively⁷⁴.

0 - absent

1 - present

12. Pinacocytes* - Cells⁷⁴ which characterise the external surface of a sponge.

0 - absent

1 - present

13. Archeocytes* - Amoeboid cells⁷⁴ found in sponges which retain totipotent capacity.

0 - absent

1 - present

14. Siliceous spicules produced by Silicateins* - Many metazoan groups possess spicule systems but amongst the animals, only sponges can produce siliceous spicules via the enzyme Silicatein. Crown-group calcareans do not produce siliceous spicules and silicateins have not been detected in homoscleromorph sponges⁷⁵.

0 - absent

1 - present

15. Spongin* - Derived from collagen, spongin is only found in demosponges⁷⁴.

0 - absent

1 - present

16. Collagen

0 - absent

1 - present

17. Nerve cells

0 - absent

1 - present

18. Acetylcholine used as a neurotransmitter

0 - absent

1 - present

19. Diffuse nervous system

0 - absent

1 - present

20. Giant axons associated with ciliary organs

0 - absent

1 - present

21. HOX/Para-HOX genes

0 - absent

1 - present

22. Epidermis with pulsatile bodies

0 - absent

1 - present

23. Xenacoelomorph cilia

0 - absent

1 - present

24. Diploblasts made of two cell layers

0 - absent

1 - present

25. Triploblasts made of three cell layers

0 - absent

1 - present

26. Striated ciliary rootlets

0 - absent

1 - present

27. Spiral cleavage with 4d mesoderm

0 - absent

1 - present

28. Colloblasts

0 - absent

1 - present

29. Coelenteron (gastrovascular cavity)

0 - absent

1 - present

30. Through-gut

0 - absent

1 - present

31. U-shaped gut

0 - absent

1 - present

32. Protonephridia (or homologous)

0 - absent

1 - present

33. Fate of blastopore

0 - protostomy

1 - deuterostomy

2 - amphistomy

34. Body cuticle with chitin

0 - absent

1 - present

35. Body cuticle with β -chitin

0 - absent

1 - present

36. Body cuticle molted

0 - absent

1 - present

37. Segmented body with jointed limbs

0 - absent

1 - present

38. Lobopods

0 - absent

1 - present

39. Slime papillae

0 - absent

1 - present

40. Telescoping mouth cone with protrudable stylets

0 - absent

1 - present

41. Respiration via metameric trachaea and spiracles

0 - absent

1 - present

42. Mixocoel (haemocoel) surrounded by segmented mesoderm

0 - absent

1 - present

43. Teloblastic segmentation

0 - absent

1 - present

44. Longitudinal ventral nerve cord(s)

0 - absent

1 - present

45. Circum-pharyngeal, collar-shaped brain with anterior and posterior rings of perikarya separated by a ring-shaped neuropil

0 - absent

1 - present

46. Introvert with scalid rings

0 - absent

1 - present

47. Flosculi

0 - absent

1 - present

48. Immunoreactivity of horseradish peroxidase (HRP)

0 - absent

1 - present

49. Feeding strategy in tentaculate metazoans

0 - predominantly micro

1 - predominantly macro

50. Trochophores

0 - absent

1 - present

51. Segmental metanephridia sacculus

0 - absent

1 - present

52. Chitinous microvillar appendages

0 - absent

1 - present

53. Parapodia with dorsal and ventral branches terminated by ?-chitinous chaetae

0 - absent

1 - present

54. Radula

0 - absent

1 - present

55. Eversible proboscis surrounded by rhynchocoel

0 - absent

1 - present

56. Complex jaw apparatus in pharynx

0 - absent

1 - present

57. Origin of mesoderm

0 - from the blastopore lips and as ectomesoderm

1 - from the walls of the archenteron or neural crest

58. Radial cleavage

0 - absent

1 - present

59. Coelom formation

0 - schizocoely

1 - enterocoely

60. Trimeric coelom

0 - absent

1 - present

61. Pharyngeal slits

0 - absent

1 - present

62. Endostyle (or homologous)

0 - absent

1 - present

63. Notochord

0 - absent

1 - present

64. Stomochord

0 - absent

1 - present

65. Haemal system with axial complex

0 - absent

1 - present

66. Calcareous endoskeleton composed of separate ossicles

0 - absent

1 - present

67. Tornaria type larva

0 - absent

1 - present

68. Longitudinal dorsal nerve cord

0 - absent

1 - present

69. Zig zag myomeres

0 - absent

1 - present

70. Endothelium that lines the inner wall of blood vessels

0 - absent

1 - present

71. Neural crest

0 - absent

1 - present

72. Neurogenic placodes

0 - absent

1 - present

73. Dorsoventral axis

0 - absent

1 - present

74. Anterior posterior axis

0 - absent

1 - present

75. Number of principal body axes* - There are concerns about body axis homology between animal lineages, and we are unable to observe particular body axes (which are developmentally defined) in fossil taxa, but sponges and placozoans have one principal body axes, cnidarians and ctenophores have two and bilaterians three. We can assess fossils against these character states.

0 - one

1 - two

2 - three

76. Compression in pharyngeal plane

0 - absent

1 - present

77. Symmetry

- 0 - bilateral
- 1 - biradial
- 2 - triradial
- 3 - tetraradial
- 4 - pentaradial
- 5 - hexaradial

78. Compression in oral aboral axis

- 0 - absent
- 1 - present

79. Compression in tentacular plane

- 0 - absent
- 1 - present

80. Mesoglea - Mesoglea, as found in cnidarians and ctenophores is scored as homologous to the mesohyl of sponges (following³⁹ but not Zhao *et al.*⁸)

- 0 - absent
- 1 - present

81. Cells in mesoglea - Cells, including skeletal elements, fibrils and amoebocytes, are found in the mesoglea of sponges, ctenophores and some cnidarians (anthozoans and scyphozoans) (following³⁹)

- 0 - absent
- 1 - present

82. Cydippid larvae

0 - absent

1 - present

83. Ciliary rosettes

0 - absent

1 - present

84. Lophophore

0 - absent

1 - present

85. Radially-arranged outgrowths from the interface between the oral and aboral regions

0 - absent

1 - present

86. Radial outgrowths fixed in globular configuration

0 - absent

1 - present

87. Radial outgrowths tentacular

0 - absent

1 - present

88. Outgrowths with pinnules

0 - absent

1 - present

89. Outer sheaths on external surface of radial outgrowths

0 - absent

1 - present

90. Outgrowths with ciliary rows

0 - absent

1 - present

91. Cushion rings or polster cells

0 - absent

1 - present

92. Cushion rings paired

0 - paired

1 - unpaired

93. Ciliary rows paired

0 - paired

1 - unpaired

94. Large compound cilia

0 - absent

1 - present

95. Large cilia fused to form locomotory plate

0 - absent

1 - present

96. Orientation of ciliary rows

0 - adaxial

1 - abaxial

97. Uniformity of ciliary rows

0 - uniform

1 - non-uniform

98. Number of ciliary rows

0 - eight

1 - eighteen

2 - six

3 - twenty four

4 - more than twenty four

5 - sixteen

99. Extension of the oral surface to form oral cone

0 - absent

1 - present

100. Aboral region represented only by apical organ

0 - absent

1 - present

101. Apical organ forming narrow pointed extension

0 - absent

1 - present

102. Gut extending into aboralmost body region
- 0 - absent
 - 1 - present
103. Stalk extending from apical/aboral region in polyp
- 0 - absent
 - 1 - present
104. Oral macrocilia
- 0 - absent
 - 1 - present
105. Oral lobes
- 0 - absent
 - 1 - present
106. Morphology of ip of oral extension
- 0 - narrow
 - 1 - voluminous
 - 2 - manubrium like
 - 3 - as margin of creeping sole
107. Mouth as margin of creeping sole
- 0 - absent
 - 1 - present
108. Pharyngeal ridges
- 0 - absent

1 - present

109. Sealing ridges of pharynx

0 - absent

1 - present

110. Macroilia on pharynx lining inside of mouth

0 - absent

1 - present

111. Ciliary dome

0 - absent

1 - present

112. Statolith

0 - absent

1 - present

113. Balancers

0 - absent

1 - present

114. Pole plates

0 - absent

1 - present

115. Aboral papillae

0 - absent

1 - present

116. Ciliary grooves

0 - absent

1 - present

117. Apical capsule

0 - absent

1 - present

118. Trifurcating ciliary grooves

0 - absent

1 - present

119. Interplate ciliary groove (ICG)

0 - absent

1 - present

120. Pharyngeal canals

0 - absent

1 - present

121. Tentacular canals

0 - absent

1 - present

122. Meridional canals

0 - absent

1 - present

123. Diverticula of meridional canals

0 - absent

1 - present

124. Circumoral ring canal

0 - absent

1 - present

125. Termination of meridional and pharyngeal canals

0 - both terminate blindly

1 - branch to form complex network

2 - united with circumoral ring canal

126. Interradial canals

0 - absent

1 - present

127. Number of interrarial canals

0 - two

1 - four

128. Agradial canals

0 - Directly branch from the infundibulum

1 - fringing along elongate oral margin

129. Aboral canals

0 - absent

1 - present

130. Anal canals and pores - This character was split in⁸ but we consider the presence of anal pores as contingent on the presence of anal canals and so have combined it.

0 - absent

1 - present

131. Paired ctenophore tentacles

0 - absent

1 - present

132. Tentilla

0 - absent

1 - present

133. Disposition of tentilla

0 - fringing along tentacles

1 - fringing along elongate oral margin

134. Tentacle sheaths

0 - absent

1 - present

135. Opening position of tentacles

0 - absent

1 - present

136. Auricles
0 - absent
1 - present
137. Brood chambers
0 - absent
1 - present
138. Skeletal elements (sclerotised arms and calyx)
0 - absent
1 - present
139. Skeletonisation restricted to aboral organ
0 - absent
1 - present
140. Tentacles extending beyond skeletal rods and outer sheaths
0 - absent
1 - present
141. Medial structures of skeletal elements
0 - absent
1 - present
142. Kinked spokes
0 - absent
1 - present

143. Spinose spokes
- 0 - absent
 - 1 - present
144. Radiating flaps/lobes
- 0 - absent
 - 1 - present
145. Circumferential oral constriction
- 0 - absent
 - 1 - present
146. Constriction type
- 0 - skirt or bell
 - 1 - lappets
147. Extracellular digestion
- 0 - absent
 - 1 - present
148. Ostia with porocytes
- 0 - absent
 - 1 - present
149. Embryonic development
- 0 - absent
 - 1 - present

150. Cnidae
- 0 - absent
 - 1 - present
151. Cnidae in gastrodermis
- 0 - absent
 - 1 - present
152. Cnidocil
- 0 - immobile
 - 1 - mobile
153. Structure of mitochondrial DNA
- 0 - circular
 - 1 - linear
154. Scyphopharynx* - muscular pharynx as an extension of the oral cone present in Scyphozoa and Hydrozoa. Hydrozoans are often described as possessing a hypostome, but this is muscular⁷⁶ and the muscle forms a sphincter, which is unlike the true scyphopharynx (e.g.⁷⁷) in which muscle is restricted and does not extend to the oral disc or form a sphincter. The actinopharynx is part of the digestive system and is not an extension of the oral cone and so these structures are not homologous. Cubozoans do not possess a pharynx⁷⁸ and it is not clear if staurozoans possess a muscular pharynx. There is some data showing the presence of a hypostome⁷⁹, but we are not able to establish whether this is muscular or not. Coronate scyphozoans do not appear to have a scyphopharynx^{80,81}.
- 0 - absent
 - 1 - present

155. Hypostome* - This is an extension of the oral cone that functions as a muscular pharynx. This character is present in hydrozoans⁷⁶ and may be present in staurozoans but we were not able to establish whether the hypostome is muscular or not⁷⁹.

156. Actinopharynx - *Ceriantharia* was previously scored as absent for this character^{8,39}, but is here scored as present following its identification in many studies, e.g.⁸². This character was previously scored as absent in poriferans and placozoans, but we have changed this to non-applicable because the possession of an actinopharynx is contingent on possession of a gut.

0 - absent

1 - present

157. Siphonoglyph (sulcus) - *Ceriantharia* was scored as absent for this character^{8,39}, but is here scored as present following its identification in many studies, e.g.⁸²

0 - absent

1 - present

158. Circular depression on basal disc

0 - absent

1 - present

159. Giant fiber nerve net (GFNN) in medusae - This character was duplicated in Zhao *et al.*⁸ and so we have deleted the alternate version.

0 - absent

1 - present

160. Stenoteles

0 - absent

1 - present

161. Euryteles

0 - absent

1 - present

162. Desomonemes

0 - absent

1 - present

163. Mastigophores

0 - absent

1 - present

164. Basitrichousisorhizas

0 - absent

1 - present

165. Apotrichousisorhizas

0 - absent

1 - present

166. Isorhizas

0 - absent

1 - present

167. Heterotrichousanisorhizas

0 - absent

1 - present

168. Birhopaloids

0 - absent

1 - present

169. Rhopalonemes

0 - absent

1 - present

170. Spirocyst

0 - absent

1 - present

171. Ptychocyst

0 - absent

1 - present

172. Polyp tentacles* - Tentacles take different forms between anthozoan and medusozoan cnidarians. Anthozoan tentacles are generally short and stout, while medusozoan tentacles are long and filiform⁸³.

0 - filiform

1 - thick

173. Two tentacle polyp stage* - Cubozoa⁶⁷ and some Staurozoa^{79,84} go through a two-tentacle polyp stage . This is not a feature seen in either scyphozoan or hydrozoan polyps and is not known to us in anthozoan polyps (e.g.⁸⁵)

0 - absent

1 - present

174. Periderm - Previously this character only encompassed chitinous skeletons, but the presence of chitins and proteins may vary independently of one another⁸⁶ and so we have rescored this character to include *Hydra*.

0 - absent

1 - present

175. Ridges or peridermal teeth - This character is contingent on producing a tube-encasing periderm. Living scyphozoans all produce peridermal teeth, as does *Eoconularia*, *Olivoooides* and *Quadrapyrgites*^{36,40,69}. Additionally, this was previously mis-scored as absent in taxa which lack a periderm.

0 - absent

1 - present

176. Ridges or peridermal teeth style* - Living coronates have continuous peridermal teeth, but this character is more variable in fossil groups. Many conulariids do not have peridermal teeth at all⁴¹, but *Eoconularia* displays intermittent/irregular teeth⁶⁹ while *Olivoooides*³⁶ and *Quadrapyrgites*⁴⁰ have one ring of teeth each. This character is altered from Leme *et al.* (2008)⁴¹, who label the first state as 'single pair', but we change this to 'Single ring'.

0 - Single ring

1 - intermittent

2 - continuous

177. Bicuspid or paired peridermal teeth* - This character is present in the fossil genera *Olivoooides*³⁶ and *Quadrapyrgites*⁴⁰, but is absent in conulariids and living scyphozoans.

0 - absent

1 - present

178. Cuticle layers in periderm

0 - absent

1 - present

179. Chitin expression

0 - restricted to basal area or to podocysts

1 - forming a tube

2 - forming a thin cuticle

180. Tube extension

0 - tube encases polyp

1 - tube does not encase polyp

181. Periderm type

0 - corneous

1 - coriaceous

2 - fibrous

182. Periderm with chitin - This character is now scored following Mendoza-Becerril *et al.* (2016)⁸⁶

0 - absent

1 - present

183. Periderm with proteins - This character is now scored following Mendoza-Becerril *et al.* (2016)⁸⁶

0 - absent

1 - present

184. Periderm externally annulated - This character is present in living scyphozoans, all sampled conulariids, *Olivoooides*, *Pseudoooides*, *Quadrapiyrgites* and *Carinachites* and the hydrozoans *Hydractinia*, *Clytia* and *Obelia* (unlike previous studies which have scored Hydrozoa as uniformly absent for this character), which show limited apical annulation⁸³. The fossil of *Auroralumina* is incomplete proximally, and so we score this as unknown.

0 - absent

1 - present

185. External annulation confined to one area of widespread* - This character defines the annulation type of the annulated hydrozoans, which do not show annulation across the entire hydroid⁸³ and is unlike living or fossil medusozoans which - apart from *Auroralumina* - are annulated across their entire surface.

0 - absent

1 - present

186. Annulation type* - This is contingent on external annulation of periderm and captures the variation between living hydrozoans, scyphozoans and fossil taxa. *Olivoooides*, *Quadrapiyrgites* and *Carinachites* are scored as having vase-like annulation, following the reconstructions of Duan *et al.* (2017)³⁶, Liu *et al.* (2014)⁴⁰ and Han *et al.* 2018)⁴⁶, along with annulated hydrozoans. All conulariids and *Pseudoooides* (following Duan *et al.* 2017³⁹) are scored as having ribs, as with all living scyphozoans. The fossil of *Auroralumina* is incomplete and so we have to score this character as unknown. The distinction is based on the presence of clear interspace regions (ribs) or not (vase-like).

0 - ribs

1 - vase-like

187. Vase-like annulation smooth or angular* - Annulation may either reach a pointed apex, or appear as smooth semi-circles. *Olivoides* and *Quadrapterygites* (following Dong *et al.* 2013³⁶ and Liu *et al.* 2014⁴⁰) are angular, like the hydrozoan *Ectopleura*, while other hydrozoans - *Clytia* and *Obelia* - have a smooth ornamentation.

0 - angular

1 - smooth

188. Ribbing as straight or arcuate* - Living scyphozoans and most ribbed fossil groups have straight ribbing, but *Carinachites* (following Han *et al.* 2018⁴⁶) has arcuate ribs, which dip basally down the periderm.

0 - straight

1 - arcuate

189. Regularity of ribbing* - Conulariids (e.g.^{68,69}) and hexangulaconulariids (e.g.³⁹) have regular external ribbing, while *Carinachites*⁴⁶ have an approximately regular ribbing, though it is clearly not as organised as in the conulariids and hexangulaconulariids. This is in contrast to living scyphozoans, which have an irregularly ornamented periderm^{87,88}.

0 - irregular

1 - approaching regular

2 - regular

190. Nodes present as ornamentation?* - This character is derived from a more inclusive character in the matrix of Leme *et al.* (2008)⁴¹, which consider the presence of nodes, tubercles and ribs on multistate character. We choose to split these states because it is not clear they are derived from the same original ornamentation and are, therefore, homologous. Nodes are present in the conulariid *Conularia*.

0 - absent

1 - present

191. Thorn-like projections?* - This is scored as present in *Carinachites*, following the reconstruction of Han *et al.* 2018⁴⁶, and as absent in all other peridermal organisms
- 0 - absent
- 1 - present
192. Periderm with faces* - This character is present in the fossil taxa *Olivoooides*³⁶, *Pseudoooides*³⁹, *Quadrapiyrgites*⁴⁰, *Carinachites*⁴⁶, all sampled conulariids and *Auroralumina*. It is not found in extant cnidarians with peridermal tubes.
- 0 - absent
- 1 - present
193. Corner sulci* - Longitudinal invaginations in a tubicolous periderm. These are absent in living tubicolous medusazoans, but are present in *Auroralumina*, conulariids^{68,69} and *Carinachites*⁴⁶.
- 0 - absent
- 1 - present
194. Deep corner sulci* - *Carinachites*⁴⁶, unlike conulariids and *Auroralumina*, has corner sulci that are deeper than the central area of the periderm is wide. This character is unknown in *Auroralumina* because the raised central ridge in the periderm only represents a minimum estimate of sulcus height.
- 0 - absent
- 1 - present
195. Periderm with faces additional to corners - Hexangulaconulariids may have many faces additional to corners. *Pseudoooides* has six faces, but *Septuconularia* is described as possessing fourteen faces³⁸, while conulariids have interadii marking a midline between corner sulci.

0 - absent

1 - present

196. Inflection (adapertural arching) of the transverse ornament at non-sulcate face margins* - Character adapted from and following⁴¹. *Olivoooides*³⁶, *Quadrapiyrgites*⁴⁰ and *Pseudoooides*³⁹ are all scored as absent. This character is not applicable for fossil taxa either lacking external peridermal ornament altogether, or for those which lack transverse ornament.

0 - absent

1 - present

197. Continuation of the transverse facial ornament across the sulcate faces* - Character adapted from scored following Leme *et al.* (2008)⁴¹. This is scored as absent in *Auroralumina*, and non-applicable in those groups which lack sulcate corners.

0 - absent

1 - present

198. External peridermal ornamentation at the non-sulcate corners* - Character adapted from Leme *et al.* (2008)⁴¹ and scored accordingly. This is scored as unknown in *Pseudoooides* and inapplicable in other fossil forms as they do not have non-sulcate corners.

0 - absent

1 - present

199. Ornament regular* - This is a new character which describes the external ornament of included fossil taxa to the exclusion of extant scyphozoans which have an irregular external ornament, which corresponds to their more irregular shape, e.g.⁸⁹.

0 - absent

1 - present

200. Transverse cross section of the corner sulcus* - Character from Leme *et al.* (2008)⁴¹ and scored accordingly. *Auroralumina* and *Carinachites*⁴⁶ are additionally scored as having angulated corner sulci.
- 0 - rounded
 - 1 - angulated
 - 2 - angulated with fold
201. Crests - longitudinal ridges in peridermal corrugated interspaces* - Character from Leme *et al.* (2008)⁴¹ and scored accordingly. This character is additionally scored as absent in, *Olivoooides*³⁶, *Quadrapiyrgites*⁴⁰ and *Pseudoooides*³⁹.
- 0 - absent
 - 1 - present
202. Periderm with lobate aperture* - aperture marked by sub-triangular oral lobes are present in *Conularia*⁶⁹, *Carinachites*⁴⁶, *Olivoooides*³⁶ and *Quadrapiyrgites*⁴⁰. They are absent in living scyphozoans and hydrozoans.
- 0 - absent
 - 1 - present
203. Periderm with differentiation into stalk and cup* - This is a new character and defines the anatomy of *Auroralumina*. All other sampled animals with peridermal tubes have a single tube with no distinction between zones.
- 0 - absent
 - 1 - present
204. Periderm tube tapering* - This is a new character and is found in living coronate scyphozoans as well as the fossil conulariids⁴¹, *Olivoooides*³⁶, *Quadrapiyrgites*⁴⁰, *Pseudoooides*³⁹ and. It is absent in living hydrozoans and the fossils *Carinachites* and *Auroralumina*.

0 - absent

1 - present

205. Steeply pyramidal taper* - This is present in conulariids⁴¹ and *Pseudoooides*³⁹, but is absent in *Olivoooides* and *Quadrapiyrgites*.

0 - absent

1 - present

206. Transverse cross section of the oral region of the polyp* - Character from and following Leme *et al.* (2008)⁴¹. This is also scored as polyhedral in all sampled fossil groups and circular in both living coronate scyphozoans and hydrozoans.

0 - circular

1 - polyhedral

207. Location of medusa formation - We score *Olivoooides* as apical or oral here because of the associated presence of ephyrae³⁶, and have all other fossils as unknown because here is no compelling case to say whether any of these fossil groups produce medusae.

0 - lateral budding from an entocodon

1 - apical or oral

2 - direct development without polyp stage

208. Type of apical medusa formation* - Conulariids have been changed from '0, strobilating', as was scored in Zhao *et al.* (2019)⁸, to '?' to reflect uncertainty in the strength of the evidence for strobilation⁴⁴ and, indeed, uncertainty as to whether conulariids produced medusae at all. *Olivoooides* is scored as present because ephyrae as known in this taxon (following Dong *et al.* 2013³⁶).

0 - Strobilation

1 - Without transverse fission

209. Strobilation type* - The cubozoan *Morbakka*, added in this manuscript, displays monodisc strobilation⁹⁰. The presence of two fused ephyae associated with *Olivoooides* suggests the presence of polydisk strobilation³⁶.

0 - polydisk

1 - monodisk

210. Polyp propagation through lateral budding

0 - absent

1 - present

211. Oocyte development

0 - oocytes develop without accessory cells

1 - oocytes develop with accessory cells

2 - oocytes develop within follicles

3 - oocytes develop from uptake of somatic or other germ line cells

212. Nectosome

0 - absent

1 - present

213. Pneumatophore

0 - absent

1 - present

214. Planula

0 - absent

1 - present

215. Feeding planula
0 - absent
1 - present
216. Planula ciliation
0 - absent
1 - present
217. Number of ectodermal cells on the planula
0 - absent
1 - present
218. Glandular cells in the planula
0 - absent
1 - present
219. Nervous cells in the planula
0 - absent
1 - present
220. Relationship between axes of planula and adult
0 - oral-aboral axis in the adult derived from the longitudinal axis of the planula
1 - oral-aboral axis in the adult derived from the transverse axis of the planula
221. Polypoid phase - nb. *Halitrephes* and *Aegina* which do not have polypoid stages were previously scored as present for some characters contingent on the presence of a polypoid phase. These characters have been changed so all polyp-contingent characters in *Halitrephes* and *Aegina* are scored as inapplicable.

0 - absent

1 - present

222. Polyp size class* - new character to characterise the difference between medusozoan polyps and anthozoans polyps. Sampled medusozoan polyps are on the order of a few mm, with the exclusion of the larger hydrozoans. There are reports of giant deep sea hydrozoan polyps which can reach meters in height, but these seem to be highly derived as compared to the rest of the group. Conulariids are on the order of a few cm, while *Carinachites* is a few mm. Given the nature of the fossil material it is not possible to discern the total height of *Olivoooides*, *Quadrapiyrgites* or *Pseudoooides*. *Auroralumina* is an obvious outlier, with a polyp height of tens of cm. These data are represented in Extended data Figure 7.

0 - a few mm

1 - a few cm

2 - tens of cm

223. Polyp organisation

0 - solitary

1 - colonial

224. Colony type* - new character to characterise the differences in colony morphology. *Auroralumina* and all colonial anthozoans (e.g. gorgonians) are arborescent while there is greater variability in medusozoans. Scyphozoans are scored as having arborescent and random colony organisation^{87,88}, while hydrozoans show arborescent (*Candelabrum*⁹¹) creeping (e.g. *Hydractinia*⁹²) and siphonophore-type colonies.

0 - arborescent

1 - creeping

2 - siphonophore-type

3 - random

225. Oral disc in polyp* - New character defining a rounded oral structure surrounded by tentacles and opening into a pharynx. This is present in the polypoid fossils *Xianguangia* and *Daihua*⁸ as well as in all anthozoans, scyphozoans, cubozoans and hydrozoans (excluding siphonophores which have reduced polyps).

0 - absent

1 - present

226. Coenenchyme* - this is a new character. Coenenchyme is mesoglea that has been penetrated by solenia (tubes) and is common in binding together colonial anthozoans. This is scored as present in colonial anthozoans and *Cambroctoconus* (following Peel 2017) and non-applicable in all solitary cnidarians and colonial medusozoan polyps.

0 - absent

1 - present

227. Mineralised coenenchyme* - This is present in *Cambroctoconus* (following Peel 2017⁵³), but is absent in living anthozoans.

0 - absent

1 - present

228. Polymorphic polyps

0 - absent

1 - present

229. Number of tentaculate whorls

0 - one

1 - two or more

230. Gut partitioned by septa
- 0 - absent
 - 1 - present
231. Septa in polyp - This was previously miscoded as present in cubozoans⁸, when they are absent⁹³.
- 0 - absent
 - 1 - present
232. Septa in medusa
- 0 - absent
 - 1 - present
233. Mesoglea in polyp septa
- 0 - absent
 - 1 - present
234. Eightfold organisation of septa* - This is present in *Cambrotoconus*^{53,94} and living octocorals.
- 0 - absent
 - 1 - present
235. Only four gastric septa present* - this is a character that defines living medusozoans^{90,93,95} and is present in *Eoconularia* after Jerre (1994)⁶⁹.
- 0 - absent
 - 1 - present

236. Pairing of mesenteries?* - this is now scored as absent in *Xianguangia* on the strength of data presented in Ou *et al.* (2017)⁹⁶ and Zhao *et al.* (2019)⁸.
- 0 - absent
 - 1 - present
237. Pairing of mesenteries
- 0 - paired
 - 1 - coupled
238. Pair morphology
- 0 - members same size
 - 1 - members different size
239. Paired secondary cycle - this is now scored as inapplicable in cubozoans (rather than absent) as they are absent for paired mesenteries (character 236).
- 0 - absent
 - 1 - present
240. Mesenterial fusion - this is now scored as absent in scyphozoans, rather than inapplicable, because they possess gastric septa considered homologous to mesenteries in this dataset.
- 0 - absent
 - 1 - present
241. Number of perfect mesenteries
- 0 - eight
 - 1 - ten
 - 2 - more than twelve

242. Types of mesentery
- 0 - only perfect mesenteries
 - 1 - perfect mesenteries not divisible
 - 2 - perfect mesenteries and imperfect mesenteries divisible
243. Directive mesentery - this is now scored as absent in scyphozoans, rather than inapplicable, because they possess gastric septa considered homologous to mesenteries in this dataset.
- 0 - absent
 - 1 - present
244. Number of directive mesentery pairs
- 0 - one pair
 - 1 - two pairs
245. Mesentery formation - This is changed from inapplicable in all medusozoans to unknown in staurozoans and scyphozoans as we assume gastric septa to be homologous to mesenteries.
- 0 - only primary tentacles
 - 1 - new septa arise in the exocoel to either side of the ventral directive
 - 2 - from ventral
 - 3 - between directive and transverse septa
 - 4 - anywhere around the circumference
246. Structure of polyp tentacles
- 0 - hollow
 - 1 - solid

247. Type of tentacles

0 - one type

1 - two types

248. Clustered tentacles

0 - absent

1 - present

249. Two-tentacle polyp stage* - This character defines a developmental stage that living cubozoans⁷⁹ and staurozoans⁹⁰ go through, but living scyphozoans and hydrozoans and anthozoans do not. Previous iterations of this matrix only scored cubozoans as going through a two-tentacle polyp stage.

0 - absent

1 - present

250. Siphonoglyph count

0 - one

1 - more than one

251. Mesenteric filament

0 - absent

1 - present

252. Mesenteric filament type

0 - two strips

1 - three strips

2 - one strip

253. Embryonic stage retained in the tube morphology
- 0 - absent
 - 1 - present
254. Tentacles retractile
- 0 - non retractile
 - 1 - retractile
255. Tentacle/coelenteron relationship
- 0 - one tentacle per endocoel and per exocoel
 - 1 - one tentacle per exocoel, multiple per endocoel
256. Catch tentacles
- 0 - absent
 - 1 - present
257. Arrangement of tentacles - This character – from Zhao *et al.* (2019)⁸ - has been split so that is now has a subordinate character (259) dealing with the number of cycles.
- 0 - scattered
 - 1 - in cycles
258. Number of cycles
- 0 - one
 - 1 - more than one
259. Acrospheres
- 0 - absent

1 - present

260. Number of tentacles in polyp

0 - six

1 - eight

2 - twelve

3 - sixteen

4 - eighteen

5 - more than twenty

261. Marginal spherules

0 - absent

1 - holotrichous

262. Acontia

0 - absent

1 - present

263. Gonads on mesenteries of 1st cycle

0 - absent

1 - present

264. Gonads on mesenteries on 2nd and subsequent cycles

0 - absent

1 - present

265. Mesogleal sphincter

0 - absent

1 - present

266. Ectodermal longitudinal muscle

0 - absent

1 - present

267. Ectodermal longitudinal muscle location

0 - tentacles and oral disc only

1 - whole body

268. Basilar musculature

0 - absent

1 - present

269. Retractor muscle

0 - weak

1 - defined

270. Parietal muscle

0 - absent

1 - present

271. Mesogleal lacunae

0 - absent

1 - present

272. Acrorhagi

0 - absent

1 - present

273. Pedal disk

0 - absent

1 - present

274. Ciliated tract on mesenteric filament

0 - absent

1 - present

275. Ephyrae

0 - absent

1 - present

276. Rhopalial lappets in ephyrae* - In many living scyphozoans, lappets flank the developing rhopalia⁹⁷, though this is absent in some forms such as *Nausithoe*⁹⁷. Rhopalial lappets are absent in *Olivoooides*, following the illustrations of Dong *et al.* (2013)³⁶.

0 - absent

1 - present

277. Number of marginal lappets* - This is a new character. In extant scyphozoans ephyrae display a number of lappets (which may house rhopalial lappets). The numbers vary in living scyphozonans, but the ephyrum of *Olivoooides* has a unique condition of five marginal lappets³⁶ (Dong *et al.* 2013), presumably reflecting the pentaradial symmetry of the polyp stage⁹⁷.

0 - five

1 - eight

2 - ten

3 - sixteen

4 - seventeen or more

278. Velar lappets* - This is a new character. Velar lappets develop between rhopalial lappets in some scyphozoans, some coronates, e.g. *Nausithoe*, and all rhizostomes⁹⁷. Velar lappets are absent in *Olivoooides*, following the illustrations of Dong *et al.* (2013)³⁶.

0 - absent

1 - present

279. Gastro-vascular star-like in shape* - This is a new character and is present in all known living scyphozoan ephyrae⁹⁷, but it's unclear whether this character is present or absent in *Olivoooides*.

0 - absent

1 - present

280. Actinula

0 - absent

1 - present

281. Organisation of nervous system

0 - not in bunches

1 - organised in bunches of gastrodermic origin

2 - organised in bunches of ectodermic origin

282. Complex ganglia associated with sensory structures in absence of CNS

0 - absent

1 - present

283. Canal system in polyp
- 0 - absent
 - 1 - present
284. Gastrodermic musculature
- 0 - absent
 - 1 - present
285. Medusoid phase
- 0 - absent
 - 1 - present
286. Arms with cluster of secondary tentacles* - This is a new character defining the anatomy of the staurozoan bodyplan: the polyp and stauromedusae.
- 0 - absent
 - 1 - present
287. Arms bifurcating* - this is a new character and defines the anatomy of the arms of *Calvadosia* to the exclusion of *Haliclystus* and *Lucernaria*⁹⁵.
- 0 - absent
 - 1 - present
288. Primary tentacles modified to anchors* - this is a new character and is present in all three sampled staurozoans⁹⁵.
- 0 - absent
 - 1 - present

289. Claustra* - This is a new character. This character defines a tissue in the gastrovascular cavity that is surrounded by mesoglea and gastrodermis and does not contact epidermis. Historically, cubozoans were described as having a claustrum, but recent work has shown that the 'claustrum' of cubozoans is actually a valve of the gastric ostium⁹⁸ and so we do not consider these structures homologous. Of our sampled taxa, only the staurozoan *Calvadosia* has a claustrum⁹⁵.

0 - absent

1 - present

290. Gonads in medusa calyx* - this is a new character which is present in *Haliclystus* and *Lucernaria* to the exclusion of *Calvadosia*⁹⁵ and other medusozoans, which do not have a calyx in the medusa stage.

0 - absent

1 - present

291. Longitudinal muscles in peduncle* - This a new character and is present in *Calvadosia* to the exclusion of other sampled staurozoans⁹⁵. No other medusozoans have a peduncle and so are scores as inapplicable.

0 - absent

1 - present

292. Number of chambers in peduncle* - This is a new character, defining variability of peduncle type in living staurozoans. Both *Haliclystus* and *Lucernaria* have four chambers, while *Calvadosia* has one chamber⁹⁵. No other medusozoans have a peduncle and so are scores as inapplicable.

0 - one

1 - four

293. Pad-like adhesive structures on tentacles derived from arms* - This is a new character, exploring tentacle variation in living staurozoans. Pad-like adhesives are present on the tentacles of *Haliclystus* and *Lucernaria*, but not *Calvadosia*⁹⁵. No other medusozoans are known to have this character.

0 - absent

1 - present

294. Pedalium of coronate type

0 - absent

1 - present

295. Rhopalia - Staurozoans are rescored as absent for rhopalia and not non-applicable because they possess rhopaliods which are not true rhopalia⁹⁹.

0 - absent

1 - present

296. Complex eyes in rhopalia

0 - absent

1 - present

297. Nerve ring in medusa

0 - absent

1 - present

298. Number of rings

0 - one

1 - two

299. Gastric filaments
- 0 - absent
 - 1 - present
300. Coronal muscle
- 0 - well developed
 - 1 - marginal and tiny
301. Pedalium of the cubozoan type
- 0 - absent
 - 1 - present
302. Velum
- 0 - absent
 - 1 - present
303. Umbrellar margin
- 0 - smooth and continuous
 - 1 - lobed
304. Tentacles in medusa
- 0 - absent
 - 1 - present
305. Tentacular bulbs
- 0 - absent
 - 1 - present

306. Statolith composition
- 0 - MgCaPO_4
 - 1 - CaSO_4
307. Septal shape in medusa
- 0 - straight
 - 1 - Y-shaped
308. Radial canals
- 0 - absent
 - 1 - present
309. Circular canal
- 0 - absent
 - 1 - present
310. Circular canal partial
- 0 - absent
 - 1 - present
311. Velarium
- 0 - absent
 - 1 - present
312. Coronal furrow
- 0 - absent
 - 1 - present

313. Gonadal location

0 - manubrium

1 - radial canals

314. Statocysts

0 - absent

1 - present

315. Statocyst location

0 - endodermic

1 - ectodermic

316. Perradial mesenteries

0 - absent

1 - present

317. Adult medusoid shape

0 - bell

1 - pyramidal

2 - cubic

3 - actinuloid

318. Shape of horizontal cross-section of the medusa

0 - circular

1 – four-part symmetry

319. Urticant rings

0 - absent

1 - present

320. Oral arms with suctorial mouths

0 - absent

1 - present

321. Tentacular insertion

0 - umbrellar margin

1 - away from margin

322. Manubrium

0 - absent

1 - present

323. Nervous system organisation

0 - GFNN absent

1 - GFNN present

324. Structure of medusa tentacles

0 - hollow

1 - solid

325. Tentacular morphology

0 - straight

1 - straight with angular inflection

326. Peronia

0 - absent

1 - present

327. Ocelli in medusa

0 - absent

1 - present

328. Peripheral system

0 - absent

1 - present

329. Umbrellar furrow

0 - absent

1 - present

330. Development of the umbrella

0 - fully developed

1 - aboral cone

331. Number of tentacular whorls

0 - one whorl

1 - two whorls

332. Velar canals

0 - absent

1 - present

333. Frenulae

0 - absent

1 - present

334. Shape of medusa tentacles

0 - filliform

1 - capitate

335. Zooxanthellae

0 - absent

1 - present

336. Ectodermal skeleton

0 - absent

1 - present

337. Composition of ectodermal skeleton

0 - proteinaceous

1 - calcitic

338. Mesogleal skeleton

0 - absent

1 - present

339. Columella

0 - absent

1 - present

340. Costae

0 - absent

1 - present

341. Octocorallian spicules

0 - absent

1 - present

342. Spicules in tentacle

0 - absent

1 - present

343. Gorgonin

0 - absent

1 - present

344. Desmocytes

0 - absent

1 - present

345. Anthozoan desmocytes* - Desmocytes are specialised cells which bind soft tissues and skeletal structures in cnidarians, but there are ultrastructural variations between desmocytes in different cnidarian groups. Anthozoan desmocytes have a pectinate margin, 'scyphozoan' desmocytes form a recessed pit (character 346), and hydrozoan desmocytes (character 347) become embedded in secretory products of adjacent cells¹⁰⁰. Tibdall (1982) only finds analogy between desmocytes, because of significant anatomical and developmental differences. However, the junctions they mediate (e.g. hemidesmosomes) are only found in cnidarians, so we view it as likely that they arose from a common ancestor. Therefore, we score these types of desmocytes as independent characters, but inapplicable in all non-cnidarian lineages.

0 - absent

1 - present

346. 'Scyphozoan' desmocytes

0 - absent

1 - present

347. Hydrozoan desmocytes

0 - absent

1 - present

#NEXUS

Begin DATA;

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Format datatype=standard interleave=yes gap=- missing=?;

MATRIX

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-----?------?------0-----0-----
-----??-----0-0-0----??

Demospongiae      1100010100111(0 1)110---0000-0000--0---00000-0--000-
0000000-0---000000----0?0---110000-----0-----0000-----0-0-0---0---000----
00-01100-0-----0-----?------?-0-----0-----
-----0-----??-----0-0-0----??

Homoscleromorpha  11000101011110010---0000-0000--0---00000-0--000-
0000000-0---000000----0?0---110000-----0-----0000-----0-0-0---0---000----
00-01100-0-----0-----?------?-0-----0-----
-----0-----??-----0-0-0----??
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Calcarea 11100101001110010--0000-0000--0---00000-0--000-0000000-0--
-000000---0?0---110000-----0-----0000-----0-0-0---0---000---00-01100-1--
-----0-----?--0-----0-----
-----0-----??-----0-0-0-----

Hexactinellida 11000101001111010--0000-0000--0---00000-0--000-0000000-
0--000000---0?0---110000-----0-----0000-----0-0-0---0---000---00-01100-
0-----0-----?--0-----0-----
-----0-----??-----0-0-0-----

Placozoa 01?00101100000010---1000-1000--0-0--00000-0--000-0000000-0--
-000000---0?0---??0000-----0-----00---0000-----0-0-0-0---0---000---0--1000--0--
-----0-----?-----0-----
-----0-----??-----0-0-0-----

Xianguangia ?????????0?0?0????1??????010-?????00000?0??0000??00000-
???0?0000?0?0??0?1???-?????1011?10-01000100-10?0-0?????????0???-?????????0---
0?10100000-10?0--?001?1?????????????1?0-----??0?????????1?0-1--
0011??000---
???????0?0?0??0?10?4????????????0????????????????????????????????????
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Daihua ?????????0?0?0????1??????10-?????00000?0??00?0??00000-
???0?0000?0?0??0?1?0?-?????101111001000100-11?0-
0?????0?0????????????0????0?10100000-10?0??001?????????????1?0-----
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0011??0????????????0?0????0??10?4????????????0????????????????????????
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Dinomischnus_venustus ?????????0?0?0????1??????010-
?????00000?0?00?0?00000-??0?0000?0????0?1???-?????101111001000110-
11?000????????0???-????????0---0?10?00000-10?0??0000?????????????1?0-----
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Xanioascus

????????0?0????????????0??????00000?0?00???00000-

???0?0000?0???0?1?1?-????11000?11???10311000?0?0????10?00?-????????0----?0--

---00-?????????-????????????-0-----?--

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Ctenorhabdodus

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???0?0000?0???0?1?1?-????11000?11???11311000?010???0?00111?-????????0----

0?11----010?????????-????????????-0-----?--

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Gemmactena

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???0?0000?0????1???-????11000?1????00111?0?0?0???0???-????????00----

0?100110111?????????-????????????-0-----?--

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Thaumactena

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???0?0000?0????1???-????11000?10???00111?0?0?0???0???-????????0----

0?100?00110?????????-????????????-0-----?--

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Galeactena

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???0?0000?0???0?1???-????11000?10???0011110?010???0???0???-????????0----

0?100?00110?????????-????????????-0-----?--

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Batofasciculus ??????????0??0????????????????????????????00000?0??00???00000-

???0?0000??0?????1???-?????1100???0???100111?0?0?0???0????0???-?????????0----

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Maotianoascus ??????????0??0????????????????0????????00000?0??00???00000-

???0?0000??0?????1???-?????11000?10???00110?0?0?0???0????????-?????????0----

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Trigoides ??????????0??0????????????????????????00000?0??00???00000-

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Euplokamis 01001111110000011111000101011100-0-000000-

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0000000000000110101111101100011111100110000000000111010001110001011111011

000----00-1000-?00000-----0-----?-----0--0--0----?--

-----0-----0-0-0-----

Mnemiopsis 01001111110000011110000101011100-0-000000-

00000010000000-0--

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100----00-1000-?00000-----0-----?-----0--0--0----?--
-----0-----0-0-0-----

Beroida 01001111110000011110000101001100-0-000000-
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-----0-----??-----0-0-0-----

Platyctenida 01001111110000011110000101011100-0-000000-
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1)111111?011000000100011111000111(0 1)0110(0 1)1111011010----00-1000--00000----
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-----0-----??-----0-0-0-----

Cestida 01001111110000011110000101011100-0-000000-
00000010000000-0--
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1)21111111111000----00-1000--00000-----0-----?-----
0--0--0----?-----0-----??-----
----0-0-0-----

Ganeshida 01001111110000011110000101011100-0-000000-
00000010000000-0--
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1)21111?11101000----00-1000--00000-----0-----?-----
0--0--0----?-----0-----??-----
----0-0-0-----

Thalassocalycida 01001111110000011110000101011100-0-000000-
00000010000000-0--
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1)21111?11101000----00-1000--00000-----0-----?-----

0--0--0---?-----0-----??-----
----0-0-0-----

Bryozoa 0110111111000001110-10011110011100-
00000000000000001000000010000000000011200--0-001(0 1)-----0---00-0000-
000000000000--0-0-0-0-0-000---000---00-1010--00000-----0-----
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-??-----0-0-0-----

Brachiopoda 0110111111000001110-100111100(0 1)11(0 1)0-
00000000000000001000000010000000000011200--0-0010-----0---00-0000-
000000000000--0-0-0-0-0-000---000---00-1010--00000-----0-----
-----?-0-----0--0--0---?-----0-----
-??-----0-0-0-----

Phoronida 0110111111000001110-10011110011100-
0000000000000000000000000000000011200--0-0010-----0---00-0000-
000000000000--0-0-0-0-0-000---000---00-1010--00000-----0-----
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-??-----0-0-0-----

Mollusca 0110111111000001110-100111100101(0 1 2)(0
1)00000000010000110101000000000000000000011200--0-000(0 1)-----0---00-1000-
000000000000--0-0-0-0-0-000---000---00-1010--00000-----0-----
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-??-----0-0-0-----

Annelida 0110111111000001110-100111100101(0 1 2)0-0000000110000(0
1)1011000000000000000000000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--
000---000---00-1010--00000-----0-----?-0-----0--0---
0---?-0-----0-----??-----0-0-
-0-----

?-----0-----??-----0-0-0---

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Enteropneusta

0110111111000001110-10011100010110-0000000010000-

000000011111011010000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000--

--000----00-1010--00000-----0-----0-----?--0-----0--0---0----

?-----0-----??-----0-0-0---

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Urochordata

0111111111000001110-10011100010110-00000000000000-

0000000101011100001001111200--0-0000-----0---00-1000-000000000000--0-0-0-0--000--

--000----00-1010--00000-----0-----0-----?--0-----0--0---0----

?-----0-----??-----0-0-0---

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Cephalochordata

0110111111000001110-10011100010110-00000000000000-

0000000111011100001100011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000--

--000----00-1010--00000-----0-----0-----?--0-----0--0---0----

?-----0-----??-----0-0-0---

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Vertebrata

0101111111000001110-10011100010110-00000000000000-

00000001(0 1)101110000111111200--0-0000-----0---00-1000-000000000000--0-0-0-0--

000----000----00-1000--00000-----0-----0-----?-----0--0---

0----?-----0-----??-----0-0-

-0-----

Entoprocta

0110111111000001110-100111100111010000000-

0000000100000000--00000000000011200--0-0001-----0---00-1100-000000000000--0-0-0-

0--000----000----00-1010--00000-----0-----0-----?--0-----0--0--

--0----?-----0-----??-----0-

0--0-----

Nematoda 0110111111000001110-100111000101010100000-011101-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
-000----00-1000--00000-----0-----0-----?-----0--0---0----?-
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Nematomorpha 0110111111000001110-100111000101110100000-010101-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
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-----0-----??-----0-0-0-----

Priapulida 0110111111000001110-100111000101111100000-011111-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
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-----0-----??-----0-0-0-----

Gastrotricha 0110111111000001110-10011110010100-000000-010000-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
-000----00-1000--00000-----0-----0-----?-----0--0---0----?-
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Tardigrada 0110111111000001110-1001110001010111010101?10001-
00000000000000000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
--000----00-1000--00000-----0-----0-----?-----0--0---0----
?-0-----0-----??-----0-0-0-----
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Kinorhyncha 0110111111000001110-100111000101?10100000-111111-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---
-000----00-1000--00000-----0-----0-----?-----0--0---0----?-
-----0-----??-----0-0-0-----

Loricifera 0110111111000001110-100111000101?10100000-011111-
000000000--00000000000011200--0-0000-----0---00-1000-000000000000--0-0-0-0--000---

Conularia

?????????0??0????????????00????00?0????????0????????????????????1?30?????
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Carinachites

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?11??
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Olivoiides

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???00?0????????0????????????????????1?40????0????????????0??0????????????
0????????????????0-----????0????????????????????1101?10??1110---010-00-01-
010101100??-0-----1?0-?---
?11????????????????1????????????????1000???1?1????????????????????
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Quadrropyrgites

?????????0??0????????????00?-

???00?0????????0????????????????1?30????0????????????0??0????????????
0????????????????0-----????0????????????????????1101?10??1110---010-00-01-
010101????-0-----1?0-?---
?11????????????????1????????????????1????????????????1????????????????
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Pseudoooides

?????????0??0????????????00?-

???00?0????????0????????????????1?10????0????????????0??0????????????

0????????????????0-----????0????????????????????????????1????10???110-020010-1?-?1-
0?0111?????--0-----1?0-?---
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Cambrocotonus

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0?????????????0?0?0?????????0?????????????????0-----
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Nematostella

0110011111000001101-1001010010-0-0-000000-

00000010000000-0--000000000000011000-110001010000--0---00-1000-00000000000--0-
0-0-0--000---000-----00-101111000110-0001000000101?0-----01--
1110110110-1---111-10010100211140000111-1001103001?0100110001-----000010-----
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Anemonia

0110011111000001101-1001010010-0-0-000000-

00000010000000-0--000000000000011050-110001010000--0---00-1000-00000000000--0-
0-0-0--000---000-----00-101111000110-0001001000101?0-----01--
1110110120-1---111-10010010211140000111-100110510110101110111-----000010-----
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Aiptasia

0110011111000001101-1001010010-0-0-000000-00000010000000-

0--000000000000011050-110001010000--0---00-1000-00000000000--0-0-0-0--000---000--
---00-101111000110-0001000000101?0-----01--1110110120-1---
111-10010010211140010111-100110501??1101110011-----000010-----
??-----10-0--0-01001

Metridium

0110011111000001101-1001010010-0-0-000000-

00000010000000-0--000000000000011050-110001010000--0---00-1000-00000000000--0-
0-0-0--000---000-----00-101111000110-0001000000101?0-----01--

1110110120-1---111-10010010211140010111-111110501011101110011-----000010-----
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Antipathes 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011050-110001010000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-1011110001?0-0001001000101?0-----
0100101011010101100011-10010000101130000?12-000100500??0--0000000-----000010---
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Ceriantharia 0110?11111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001010000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0001001000111?0-----01--
1010110120-1---111-10010?00201020100011-0001105001?0110000001-----000000-----
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Corynactis 0110011111000001101-1001010010-0-0-000000-
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0-0-0--000---000-----00-101111000110-0001001000101?0-----01--
1110110100-1---111-10010010210-40000-12-110111500??0110000010-----000010-----
-----??-----10-0--0-01001

Montastraea 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011050-110001010000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0001001000101?0-----
0100111011010101100111-10010010210-40000-12-100111500??0--0000000-----000010-----
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Porites 0110011111000001101-1001010010-0-0-000000-00000010000000-
0--000000000000011050-110001010000--0---00-1000-000000000000--0-0-0-0--000---000--
---00-101111000110-0001001000101?0-----
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-----??-----1110110-01001

Acropora 0110011111000001101-1001010010-0-0-000000-
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0-0-0--000---000-----00-101111000110-0001001000101?0-----
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Parazoanthus 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001010000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0001001000101?0-----
0100101011010101100111-10010110221110000011-100110500??0100011001-----000010---
-----??-----10-0--0-01001

Anthomastus 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001011000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0000001000001?0-----
0100101011010101100011-11011-00001000000010-000100100??0??0000001-----000010---
-----??-----00-1--1101001

Keratoisidinae 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001011000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0000001000001?0-----
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-----??-----00-1--1101001

Nephtyigorgia 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001011000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0000001000001?0-----
0100101011010101100011-11011-00001000000010-000100100??0??0000001-----000010---
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Leptogorgia 0110011111000001101-1001010010-0-0-000000-
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0-0-0--000---000-----00-101111000110-0000001000001?0-----

0100101011010101100011-11011-00001000000010-000100100??0??0000001-----000010---
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Scleronephtha 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001011000--0---00-1000-000000000000--0-
0-0-0--000---000-----00-101111000110-0000001000001?0-----
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Virgularia 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011000-110001011000--0---00-1100-000000000000--0-
0-0-0--000---000-----00-101111000110-0000001000001?0-----
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Haliclystus 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011030-100001010000--0---00-1-00-000000000000--0-0-
0-0--000---000-----00-10111?1??0000010000100000011---00-010-----11-12--
1001000110-0---01111110--00--0-?0001---00-00-0100--0??000000-0---
00?121101010110000-110001?-10000010-0110001000000000000100-0--0001100

Lucernaria 0110011111000001101-1001010010-0-0-000000-
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0-0--000---000-----00-10111?1??0000010000100000011---00-010-----11-12--
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Calvadosia 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011030-100001010000--0---00-1-00-000000000000--0-0-
0-0--000---000-----00-10111?1??0000010000100000011---00-010-----11-12--
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00?121111101000000-110001?-10000010-011000100-00000000100-0--0001100

Alatina 0110011111000001101-1001010010-0-0-000000-00000010000000-
0--000000000000011010-100001010000--0----00-1-00-00000000000--0-0-0-0--000----000---
--00-1011101--0001110100100000011---10-011-----11-1?--1010??0100-1---
0101001-----1001---00-00-0100--0??000000-0----0111210-00---
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Chironex 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011010-100001010000--0----00-1000-00000000000--0-
0-0-0--000----000-----00-1011101--0001110100100000011---10-011-----10(0
1)??--1010??0100-1---0101001-----1001---00-00-0100--0??000000-0----0111210-00---
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Morbakka 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011010-100001010000--0----00-1000-00000000000--0-
0-0-0--000----000-----00-1011101--0001110100100000011---10-011-----
101??--1010??0100-1---0101001-----1001---00-00-0300--0??000000-0----0111210-00---
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Atolla 0110011111000001101-1001010010-0-0-000000-00000010000000-
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Stephanoscyphistoma 0110011111000001101-1001010010-0-0-000000-
00000010000000-0--000000000000011030-110001010000--0----00-1000-00000000000--0-
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Nausithoe 0110011111000001101-1001010010-0-0-000000-
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0-0-0--000----000-----00-10111010000010100001000000001120110011110-000000-001-0-

10010010010--10????010(0 1)31---01111010--00--0-?1000---00-0100500--0??000000-
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Aurelia 0110011111000001101-1001010010-0-0-000000-00000010000000-
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