

1 **An exceptionally preserved euarthropod with**  
2 **unique feather-like appendages from the**  
3 **Chengjiang biota**

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21 **Abstract** Micro-CT scanning of the Cambrian euarthropod *Chuandianella*  
22 **ovata** reveals unprecedented three-dimensional soft-part details. It has an

23 **elongate uniramous antennule and a short uniramous second appendage,**  
24 **followed by ten homonomous biramous appendages, each comprising a**  
25 **short paddle-shaped exopod and a unique feather-like endopod with at**  
26 **least 27 podomeres each of which bears a long blade-like endite with a**  
27 **short terminal seta. Based on its carapace and previously known soft-part**  
28 **anatomy *C. ovata* was compared with the Burgess Shale mandibulate**  
29 **euarthropod *Waptia*. However, *Waptia* has recently been shown to bear**  
30 **specialized head appendages that are interpreted as a mandible and**  
31 **maxillula, posterior to which are four appendages each with five-**  
32 **segmented endopods. In contrast, we interpret *Chuandianella* as an**  
33 **‘upper’ stem-group euarthropod that possessed neither a differentiated**  
34 **mandible nor a maxillula. *Chuandianella* further demonstrates that early**  
35 **Cambrian ‘upper’ stem-group euarthropods were experimenting with a**  
36 **range of different limb arrangements and morphologies.**

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## 39 **Introduction**

40 During the Cambrian Period bivalved arthropods formed a numerically  
41 abundant and widespread component of marine ecosystems in benthic,  
42 nektobenthic and pelagic settings (*Williams et al., 2007, 2015*). They are  
43 among the most abundant animals in the Chengjiang Lagerstätte of China  
44 (*Zhao et al., 2012; Hou et al., 2017*) and the North American Burgess Shale  
45 Lagerstätte (*Briggs et al., 1994*). Many of these arthropods are species that  
46 have been assigned to Bradoriida Raymond, 1935, a group common worldwide  
47 and with very rare exceptions known only from their bivalved carapaces

48 (*Williams et al., 2007*). Where they preserve soft-part anatomy in many cases  
49 conventional classifications based on carapace morphology break down. The  
50 markedly different arthropod body plans revealed beneath the bivalved  
51 carapace include stem euarthropods (*Zhai et al., 2019a*), and mandibulates  
52 (*Vannier et al., 2018*) including stem pan-crustaceans (*Zhai et al., 2019b*).

53 Recent Micro-CT scanning of fossil arthropods has in many cases  
54 revolutionised our understanding of their soft-part anatomy. This has become  
55 particularly apparent in the study of the Cambrian (Series 2, Stage 3)  
56 Chengjiang biota arthropods of China (e.g., *Liu et al. 2020*), which preserve  
57 components of their original three-dimensional soft-part anatomy, including fine  
58 details of appendages (e.g., *Zhai et al., 2019a,b; Liu et al., 2020*). Here we  
59 describe newly micro-CT analysed specimens of the Chengjiang bivalved  
60 arthropod *Chuandianella ovata* (*Li, 1975*), which show remarkably preserved  
61 soft parts. We undertake a detailed morphological analysis of this new material  
62 to assess the hypotheses of the possible affinity and lifestyle of this bivalved  
63 taxon, and its implications for understanding the diversity and evolution of early  
64 euarthropods

65

## 66 **Results**

### 67 **Systematic palaeontology**

68 Phylum: Euarthropoda Lankester, 1904

69

### 70 **Genus (Monotypic)**

71 *Chuandianella* Hou and Bergström, 1991

72

73 **Generic and species diagnosis (amended after Hou and Bergström)**

74 Bivalved euarthropod bearing a uniramous antennule consisting of at least ten  
75 podomeres; a short, uniramous second appendage with at least six podomeres;  
76 ten other, homonomous appendages, each comprising a short paddle-shaped  
77 exopod and a feather-like endopod bearing at least 27 podomeres each with a  
78 long blade-like endite bearing a terminal seta; and an abdomen comprising four  
79 apodous segments, plus a tailpiece with two elongate, flap-like caudal  
80 structures.

81

82 **Type species**

83 *Mononotella ovata* Li, 1975

84 Note: The author's name "Li" is spelled "Lee" in some publications.

85

86 **Type horizon and locality**

87 Chiungchussu Formation, *Eoredlichia-Wutingaspis* trilobite biozone, Cambrian  
88 Series 2, Stage 3. Chiungchussu, Kunming, Yunnan Province, China.

89

90 **Species**

91 *Chuandianella ovata* (Li, 1975).

92

93 **Holotype**

94 Repository given (*Li, 1975*) as the Institute of Southwestern Geosciences,  
95 Chengdu, China (now known as The Chengdu Centre of the Geological Survey  
96 of China). Collection number YN6303, specimen number YO10; designated  
97 and figured Li 1975, pl. 3, fig. 16.

98

99 **Key synonymy**

100 *Mononotella ovata* Lee, 1975, sp. nov., p. 65, pl. 3, figs 16, 17; *Mononotella*  
101 *viviosa* Lee, 1975, sp. nov., p. 65, pl. 3, fig. 18; ?*Mononotella marginia* Lee,  
102 1975, sp. nov., pl. 3, figs 19, 20; *Chuandianella ovata* (Li, 1975), Hou and  
103 Bergström, 1997, p. 41, fig. 37 (q.v. for earlier synonymy); *Chuandianella ovata*  
104 (Li, 1975), Liu and Shu, 2008, p. 358, text-figs 1-3; *Chuandianella ovata* (Lee,  
105 1975), Hou *et al.*, 2017, p. 238, figs 20.61, 20.62; *Chuandianella ovata*, Ou *et*  
106 *al.*, 2020, figs 1A,C,E,G,H,J, 2, 3.

107

108 **Species diagnosis**

109 As for the genus.

110

111 **Description**

112 The carapace is up to 1.45 cm long (Liu and Shu, 2008), ‘bivalved’ along a  
113 median fold, but lacking an articulating hinge. Valves are strongly postplete in  
114 lateral outline and lack lobation; they have a narrow incurved free margin  
115 (Figures 1h, 2a,b, 4a). In some individuals (Figure 3e, j; Supplementary Figure  
116 7a) the external carapace surface is finely pitted. The body is up to 3 cm long  
117 (Ou *et al.*, 2020) and consists of 18 segments (Figures 2b, 4). It is attached to  
118 the carapace dorsally by at least the first four (possibly five) segments (Figure  
119 1h). Pedunculate stalked eyes originate from the first (ocular; presumed  
120 protocerebral) segment and protrude beyond the anterior margin of the  
121 carapace (e.g., Figure 3f,g; Supplementary Figures 4, 6). The eye has a dark-

122 coloured central zone and a light-coloured outer zone, with a well-defined visual  
123 surface (*Figure 3g; Supplementary Figure 6b*).

124 The antennule is uniramous, narrow and about 30% longer than the  
125 carapace; it consists of at least 10 podomeres and gradually tapers distally  
126 (*Figures 1a, 2b, 3a,i; Supplementary Figures 5a, 6a*). The proximal podomere  
127 is stouter than the rest and the more distal podomeres are longer; each  
128 podomere bears up to five short stiff setae on the adaxial surface (*Figure 3b-d;*  
129 *Supplementary Figure 5*). The second appendage is uniramous, consisting of at  
130 least six, gradually tapering podomeres; it is presumed to represent an  
131 endopod (*Figures 1d,e,f, 3k, 4; Supplementary 8b,c*). Its terminal podomere is  
132 elongate, rod-like and apparently lacks a terminal claw (*Figures 1f, 3k*); it is  
133 uncertain if it has setae or not (*Supplementary Figure 8c*). Posterior to the  
134 second appendage there are ten homonomous appendages. Each consists of a  
135 short paddle-shaped exopod (*Figures 1b,g; Supplementary Figure 1a,b, 2a,b,*  
136 *7d*) and a long endopod that is more robust proximally and gradually tapers  
137 distally (*Figure 1j*); evidence of the basipod is not apparent. The endopod bears  
138 at least 27 podomeres, each with a long blade-like endite bearing a short  
139 terminal seta (*Figure 1c,j, 4; Supplementary Figures 2c, 3b, 5b*), giving an  
140 overall feather-like morphology. The endites in some specimens are preserved  
141 perpendicular to the axis of the endopod and parallel to each other (e.g., *Figure*  
142 *1c,h*), but in other specimens they overlap each other (e.g., *Figure 1j*) indicating  
143 flexible movement and/or taphonomic displacement. The posterior part of the  
144 trunk (= abdomen *sensu Vannier et al., 2018* and *Zhai et al., 2019b*), which  
145 consists of a tubular section of four sclerites and a tailpiece bearing two long,  
146 blade-like structures, is apodous (*Figures 1a,b, 2a,b*). The carapace covers

147 about the first nine segments of the body; the more posterior segments  
148 protrude posteriorly from the carapace via a gape (*Figure 2a,b*). Two  
149 specimens bear tiny sub-circular/ovoid objects, mostly 400–600 µm across and  
150 loosely scattered within the left valve (*Figures 1j*) or roughly arranged in  
151 multiple rows (*Supplementary Figure 9a*); they are interpreted as eggs. In the  
152 better-preserved specimen YKLP 16258 (*Supplementary Figure 9*) at least 48  
153 eggs are associated with a single valve.

154

## 155 Discussion

### 156 ***Chuandianella ovata* is not a waptiid**

157 Based on carapace morphology *C. ovata* was originally (*Li, 1975*) assigned to  
158 the Cambrian bradoriid *Mononotella* (for which, see *Siveter and Williams, 1997*)  
159 and was subsequently designated (*Hou and Bergström, 1991*) as the type  
160 species of *Chuandianella*. *Chen et al. (1996)* and *Chen (2004)* opined that *C.*  
161 *ovata* is a waptiid, related to the Burgess Shale *Waptia fieldensis* Walcott,  
162 1912. *Hou and Bergström, (1997)* tentatively included *Chuandianella* in the  
163 Family Waptiidae Walcott, 1912, though noted it had ‘not yet been studied in  
164 detail’. Both taxa have carapaces with a postplete outline lacking lobes and  
165 nodes, a dorsal median fold without an articulating hinge, a trunk with four  
166 apodous segments and a tailpiece with two caudal structures (*Chen et al.,*  
167 *1996; Hou and Bergström, 1997; Chen, 2004*). With some exceptions (*Liu and*  
168 *Shu, 2004, 2008; Hou et al. 2017*) a possible affinity with waptiids has  
169 persisted, as in the study of the bivalved *Paulotermius spinodorsalis* from the  
170 Cambrian of Greenland (*Taylor, 2002*) and in *Vannier et al. (2018)* who  
171 considered *Chuandianella* to be a mandibulate euarthropod.

172 *C. ovata* differs in morphology from both *P. spinodorsalis* and *W.*  
173 *fieldensis*. The biramous trunk appendages of *P. spinodorsalis*, each with a  
174 short feather-like endopod and a long, paddle-shaped exopod, distinguish it  
175 from *C. ovata*, whilst *P. spinodorsalis* also possesses a longer carapace (9.1 -  
176 46.3 mm; *Taylor, 2002*) compared with that of *C. ovata* (5.15 - 13.09 mm; see  
177 Table 1). *Waptia fieldensis* is interpreted as possessing a specialised mandible  
178 and maxillula, whilst the four post-maxillular appendages are also specialized  
179 with 5-segmented endopods (*Vannier et al., 2018*). These important and  
180 diagnostic features, together with the longer carapace of *W. fieldensis* (in  
181 adults, 10.99 - 24.54 mm; *Vannier et al., 2018*), distinguish it from *C. ovata*.

182 The morphology of *Chuandianella* does not support its assignment to  
183 crown-group Mandibulata, not least because of the absence of head segments  
184 bearing mandibles and maxillulae (see *Scholtz and Edgecombe 2006*). Here  
185 we interpret *Chuandianella* as an 'upper' stem-group euarthropod (*sensu*  
186 *Ortega-Hernández, 2016*) based on its possession of a deutocerebral first  
187 appendage pair, a multi-segmented head region with, in this case, two pairs of  
188 differentiated post-ocular limbs, complete arthropodization, including post-oral  
189 biramous limbs. We cannot determine the presence of a posterior facing mouth  
190 beneath a hypostome/labrum complex.

191

### 192 **The feather-like endopods of *C. ovata* are unique**

193 Previous studies of *C. ovata* (e.g., *Liu and Shu, 2008*) failed to identify the  
194 paddle-shaped exopods of its trunk limbs, and the feather-like endopods  
195 (*Figures 1c,j; 2a*) were mistakenly interpreted as exopods. The extremely long  
196 blade-like endopodal endites of *C. ovata* are the only ones of their kind known



197 in a Cambrian bivalved euarthropod and further demonstrate that early, ‘upper’  
198 stem-group euarthropods were experimenting with a wide array of different limb  
199 arrangements and morphologies (*Zhai et al., 2019a*). Possible comparable  
200 structures occur in *W. fieldensis*: six pairs of annulate post-cephalothoracic  
201 seemingly single-branched appendages fringed with long lamellae (*Vannier et*  
202 *al., 2018*) were interpreted as possible endopods or, more likely, basipods of a  
203 unique morphology within Euarthropoda (*Vannier et al., 2018*). The morphology  
204 of the endopods in *C. ovata* also bear comparison with those of the bradoriid  
205 *Kunmingella douvillei* (Mansuy, 1912), though in the latter the endopodal  
206 endites are less numerous (*see Zhai et al., 2019a*), are cylindrical rather than  
207 blade-like, and are significantly shorter. Without a full understanding of their 3-D  
208 morphology, the endopods of *Kunmingella* were initially misinterpreted as  
209 exopods (*Hou et al., 1996, fig. 5*).

210

### 211 **The bivalved carapace is an unreliable indicator of affinity**

212 Previous studies have clearly demonstrated that the taxonomic assignment of  
213 early Palaeozoic ostracod crustaceans may be flawed if based on the  
214 morphology of their bivalved carapace alone (*Siveter et al., 2012, 2018*).  
215 Similarly, analysis of three bivalved arthropods referred to the Bradoriida has  
216 demonstrated that their carapace morphology when considered alone is an  
217 unreliable basis for classification: the carapace houses markedly different soft-  
218 bodies that include both stem-euarthropods and mandibulate-like euarthropods  
219 (*Zhai et al., 2019a*). The data presented here on the soft-part anatomy of *C.*  
220 *ovata* provides further evidence that carapace morphology alone is a poor  
221 indicator of the affinity of bivalved euarthropods and that the diversity of

222 morphologies seen in bivalved fossil euarthropods is greater than previously  
223 appreciated.

224

225 **Mode of life of *C. ovata***

226 The morphology of the biramous appendages of *C. ovata* is not compatible with  
227 ambulatory activity on the seabed. The feather-like endopods and well-  
228 developed tail fan of *C. ovata* may have aided swimming/propulsion and  
229 manoeuvrability (*Figures 1c,j, 4, 5*; see also *Liu and Shu, 2008*). A possible  
230 nektonic lifestyle is also supported by its occurrence: *C. ovata* is relatively  
231 common and is widespread in the Cambrian of southwest China (*Hou et al.,*  
232 *2017*). It is known from similar Cambrian stratigraphical levels (Series 2, Stage  
233 3) in Sichuan, Guizhou and southern Shaanxi provinces (although only material  
234 from Yunnan has yielded soft-part anatomy). *C. ovata* may have used its long  
235 feather-like endopodal endites for filter-feeding, capturing small-sized organic  
236 material. Its long setate antennules presumably had a sensory function,  
237 perhaps to detect predators, food or monitor environmental conditions. The  
238 diminutive second appendage may have functioned like the main ramus of the  
239 first maxillula of living crustaceans such as ostracods (*Meisch, 2000*) to support  
240 food manipulation other than mastication. The stalked eyes are well developed,  
241 protrude beyond the carapace and their preservation in various orientations  
242 suggests that they were mobile to provide multi-directional vision (*Figures 1a,*  
243 *2a,b, 3a,f,i; see also Supplementary Figures 4,6a*). The radius of curvature of  
244 the eye is greater laterally than frontally, suggesting better resolution of the  
245 lateral field (*Strausfeld, 2015*). That *C. ovata* occurs in supposed coprolites in

246 the Chengjiang biota (*Chen and Zhou, 1997; Vannier and Chen, 2005*)  
247 indicates that it was a prey or carrion item.

248         The bivalved carapace of *C. ovata* apparently functioned not only for  
249 protection of soft parts but also apparently as a surface for the attachment of its  
250 eggs. *Ou et al. (2020)* reported egg-bearing specimens of *C. ovata* and  
251 compared possible reproductive modes of *C. ovata* and *W. fieldensis* (the latter  
252 reported by *Caron and Vannier, 2016*) based on the size, number and  
253 morphology of eggs. They determined that the eggs of *C. ovata* were smaller  
254 (0.5 mm versus 2.0 mm in diameter) than those of *W. fieldensis* but each  
255 individual animal carried significantly more eggs ( $\leq 100$  versus  $\leq 26$  per clutch)  
256 than *W. fieldensis*, implying different reproductive strategies (*Ou et al., 2020*).  
257 Our observations on our egg-bearing specimens of *C. ovata* (*Figure 1i*;  
258 *Supplementary Figure 9*) generally confirm the size, number and position of  
259 eggs as indicated by *Ou et al. (2020)*. Since *C. ovata* is morphologically distinct  
260 from *W. fieldensis* differences in brooding strategies between these taxa are  
261 not surprising. Sexual dimorphism has been suggested for *C. ovata*, by which  
262 the valves of supposed males are larger, with a greater height to length ratio,  
263 and have a pitted rather than smooth surface (*Liu and Shu, 2008*). As only one  
264 of the two egg-bearing specimens in our material has pitted valves (*Figure 3j*)  
265 ornament should not be regarded as a possible dimorphic character. We have  
266 been unable to replicate the observation (*Liu and Shu, 2008*) that female and  
267 male reproductive systems are preserved in some specimens.

268

269 **Conclusions**

270 Micro-CT scanning of the stem group euarthropod *Chuandianella ovata* from  
271 the Cambrian Chengjiang Lagerstätte reveals unprecedented details of its soft-  
272 part anatomy. Notably, *C. ovata* possessed differentiated first and second  
273 appendages, and a further ten homonomous appendages each with a short  
274 paddle-shaped exopod and a feather-like endopod of at least 27 podomeres.  
275 This morphology clearly differentiates *Chuandianella* from the Cambrian  
276 mandibulate euarthropod *Waptia*, to which it has been consistently compared.

277         The feather-like endopods of *C. ovata* attest to the wide diversity of limb  
278 arrangements and morphologies developed by early Cambrian, ‘upper’ stem-  
279 group euarthropods. Together with the well-developed tail fan of *C. ovata*,  
280 these may have facilitated a nektonic lifestyle, a notion that is also supported by  
281 the widespread occurrence of *C. ovata* in the Cambrian of southwest China. Its  
282 well-developed stalked eyes would have provided multi-directional vision for  
283 various uses including detection of predators. That *C. ovata* occurs in supposed  
284 coprolites in the Chengjiang biota also indicates that it was a prey or carrion  
285 item.

286

## 287 **Material and methods.**

288 New specimens of *C. ovata* were collected from the Yu’anshan Member,  
289 Chiungchussu Formation, *Eoredlichia-Wutingaspis* trilobite biozone, Cambrian  
290 Series 2, Stage 3, Yunnan Province (see *Hou et al., 2017*), at Mafang,  
291 Ercaicun and Jianshan in Haikou, Kunming (*Supplementary Table 1*). Fourteen  
292 specimens which revealed appendage morphology in high fidelity were  
293 selected for detailed study. Specimens are mainly housed in the Yunnan Key

294 Laboratory for Palaeobiology (YKLP), Yunnan University, Kunming, or in the  
295 Yunnan Geological Survey (Hz-f-4-777, He-f-6-4-294).

296 Fossil structures exposed on the surface of the rock slabs were imaged  
297 with a Nikon D3X camera with an Af-S VR105 macro lens (*Figure 3*) and a  
298 Keyence VHX6000 stereo-microscope (photographs in all other figures). Fossil  
299 structures hidden within the slabs (*Figures 1, 2*) were revealed using a Zeiss  
300 Xradia 520 Versa X-ray Microscope. Scanning pixel size ranged from 3.4 to  
301 26.8  $\mu\text{m}$ , depending on the size of the scanned region and the slab. The digital  
302 data from each specimen, in the form of a series of one to a few thousand TIFF  
303 images representing cross-sections through different parts of the slab, were  
304 processed with Drishti software (Versions 2.4) to generate 3-D models of the  
305 fossils.

306

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314 Figure 5. The Jianshan Subsidiary of the Yunnan Phosphate Chemical Group  
315 Co. Ltd. provided invaluable help facilitating field work. The Yunnan Geological  
316 Survey granted access to two of the specimens.

317

## 318 Additional files

319 **Supplementary files**

320 Supplementary Table 1. Dimensions of specimens of *Chuandianella ovata*  
321 investigated in this study.

322

323 Supplementary Figure 1. *Chuandianella ovata*, YKLP 16216. (A) Microscope  
324 image of specimen on rock slab. Scale bar = 0.8 mm. (B) Micro-CT stereopair  
325 image. Scale bar = 2.0 mm. Abbreviations as for Figures 1-3. Italics indicate a  
326 right-side appendage. Note: The soft parts of this specimen are taphonomically  
327 dislocated and are flipped vertically, so that this figure shows the dorsal views  
328 of the carapace and the ventral views of the trunk and appendages, with the  
329 left appendages associated with the right valve while the right appendages are  
330 associated with the left valve (cf. *Figure 1b,g*).

331

332 Supplementary Figure 2. *Chuandianella ovata*, YKLP 16215a. (A) Microscope  
333 image of specimen on rock slab, dorsal view. Note that the posterior part of the  
334 trunk is missing. Scale bar = 3.3 mm. (B,C) Micro-CT images of anterior part,  
335 stereo-pairs (anterior end to the left). Scale bar = 3.1 mm. (B) Dorsal view. (C)  
336 Ventral view. Abbreviations as for Figures 1-3. Italics indicate a right-side  
337 appendage.

338

339 Supplementary Figure 3. *Chuandianella ovata*, YKLP 16217 (for microscope  
340 image of this specimen see *Figure 3a-e*), stereo-pairs of micro-CT images.  
341 Scale bar = 5.0 mm. (A) Dorsal view of anterior part. (B) Ventral view of  
342 anterior part. Abbreviation additional to Figures 1-3: cz, central zone of the eye  
343 with dark coloration. Italics indicate a right-side appendage.

344

345 Supplementary Figure 4. *Chuandianella ovata*, YKLP 16218, microscope  
346 images (for micro-CT images of this specimen see *Figure 1a, c*). Scale bar =  
347 1.0 mm. (A) YKLP 16218a, dorsal view of anterior part. (B) YKLP 16218b,  
348 ventral view of anterior part; posterior part is buried in sediment. Abbreviations  
349 as for Figures 1-3. Italics indicate a right-side appendage.

350

351 Supplementary Figure 5. *Chuandianella ovata*, He-f-6-4-294. (A) Microscope  
352 image, oblique-right view; the posterior part of the trunk is missing. Scale bar =  
353 1.0 mm. (B) Stereo-pair of micro-CT image, details of anterior part of specimen,  
354 oblique-left view (viewed from underside of slab). Scale bar = 1.2 mm. (C)  
355 Details of setae on left a1 (white rectangle in A). Scale bar = 0.5 mm.  
356 Abbreviations as for Figures 1-3. Italics indicate a right-side appendage.

357

358 Supplementary Figure 6. *Chuandianella ovata*, Hz-f-4-777. (A) Microscope  
359 image, dorsal view; the left and posterior parts of the specimen are missing.  
360 Scale bar = 1.8 mm. (B) Details of left eye. Scale bar = 0.7 mm. (C) Stereo-pair  
361 of micro-CT image, ventral view of anterior part. Scale bar = 1.0 mm.  
362 Abbreviations as for Figures 1-3. Italics indicate a right-side appendage.

363

364 Supplementary Figure 7. *Chuandianella ovata*, YKLP 16256. (A) Microscope  
365 image, showing pits on left valve. Scale bar = 0.4 mm. (B) Microscope image,  
366 dorsal view. Scale bar = 0.9 mm. (C,D) Stereo-pairs of micro-CT images. The  
367 posterior part of the body is reflexed so that it emerges from the anterior end of

368 the carapace. Scale bar = 2.0 mm. (C) Dorsal view. (D) Ventral view.

369 Abbreviations as for Figures 1-3. Italics indicate a right-side appendage.

370

371 Supplementary Figure 8. *Chuandianella ovata*, YKLP 16257. (A) Microscope

372 image, dorsal view. Scale bar = 2.3 mm. (B,C) Stereo-pairs of micro-CT

373 images. (B) Dorsal view. Scale bar = 5.0 mm. (C) Ventral view of the anterior

374 part (white rectangle in B), showing a2. Scale bar = 1.5 mm. Abbreviation

375 additional to Figures 1-3: uf, unidentified fossil. Italics indicate a right-side

376 appendage.

377

378 Supplementary Figure 9. *Chuandianella ovata*, YKLP 16258, an egg-bearing

379 specimen, microscope images. (A) Overview, oblique-right view. Scale bar =

380 2.0 mm. (B) Details of eggs (white rectangle in A). Scale bar = 1.4 mm.

381 Abbreviations as for Figures 1-3. Italics indicate a right-side appendage.

382

### 383 **Data availability**

384 Computed tomography data will be available on Dryad upon acceptance by the

385 journal.

386

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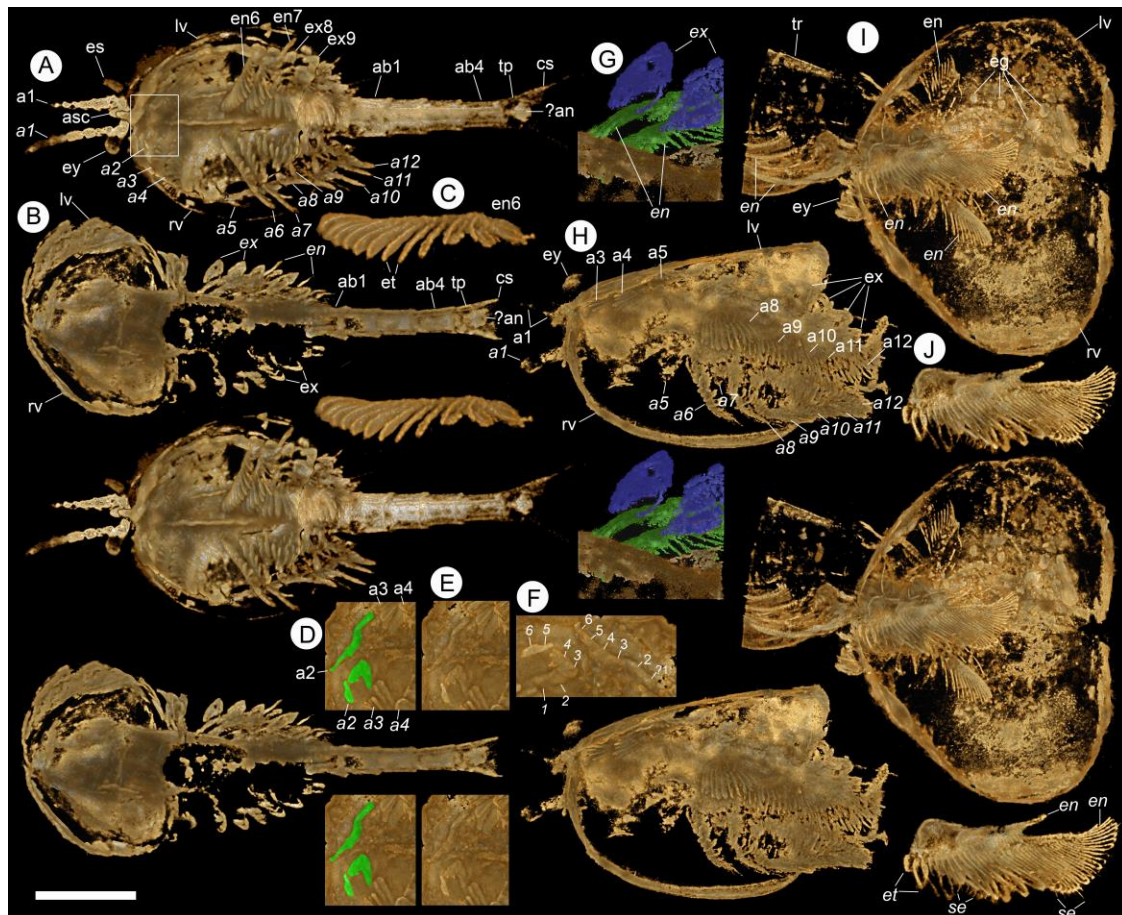
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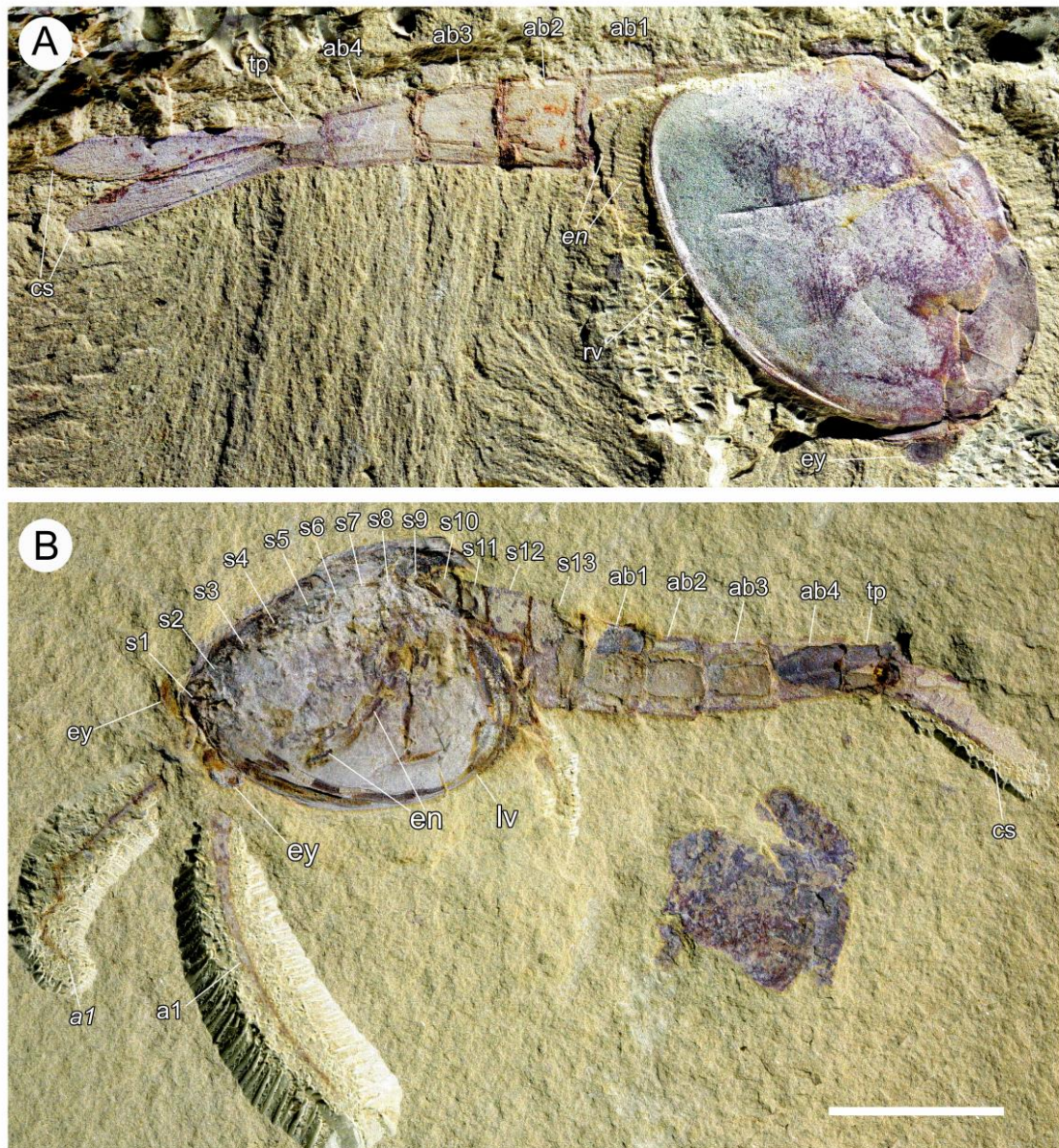
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503

504 **Figure 1.** Micro-CT images of *Chuandianella ovata*. (A,C-F) YKLP 16218. (A)  
505 Ventral view. Scale bar = 5.0 mm. (C) Endopod of 6<sup>th</sup> appendage showing  
506 endites. Scale bar = 1.6 mm. (D) Ventral view (white rectangle in A), showing  
507 details of second appendage (a2, green). Scale bar = 2.0 mm. (E) Same as D  
508 but with a2 not coloured. Scale bar = 2.0 mm. (F) Close-up view of 2<sup>nd</sup>  
509 appendages (rotated by 90 degrees with anterior to upper position), with  
510 podomeres numbered. Scale bar = 1.4 mm. (B,G) YKLP 16216. (B)  
511 Taphonomically deformed specimen, showing ventral view of the carapace and  
512 dorsal view of the soft parts (cf. **Supplementary Figure 1**). Scale bar = 3.8  
513 mm. (G) Dorsal view of part of right side of the body, showing exopods (blue)  
514 and endopods (green). Scale bar = 1.4 mm. (H) YKLP 16238, left lateral view,  
515 showing endopods and exopods of trunk appendages. Scale bar = 4.9 mm.  
516 (I,J) YKLP 16239. (I) Ventral view, showing *circa* 20 eggs within the left valve.  
517 Scale bar = 4.3 mm. (J) Endopods of 3<sup>rd</sup> and 5<sup>th</sup> (?) appendages showing long  
518 blade-like endites each with a terminal seta. Proximally in this image two  
519 endopods overlap, giving the false impression of setae along the lateral  
520 margins of the endites. Scale bar = 3.4 mm. All panels are stereo-pairs.  
521 Abbreviations: a1, antennule; a2, second appendage; a3-a12, biramous  
522 appendages; ab1-4, abdominal segments 1 to 4; an, anus; asc, anterior  
523 sclerite; cs, caudal structure; eg, egg; en, endopod; es, eye stalk; et, endite;  
524 ex, exopod; ey, stalked eyes; lv, left valve; rv, right valve; se, seta; tp, tailpiece;  
525 tr, trunk. Italics indicate a right-side appendage.

526



527

528 **Figure 2.** Photographs of *Chuandianella ovata*, showing overall morphology

529 and segmentation of the body. (A) RCCBYU 10272, right lateral view. Scale

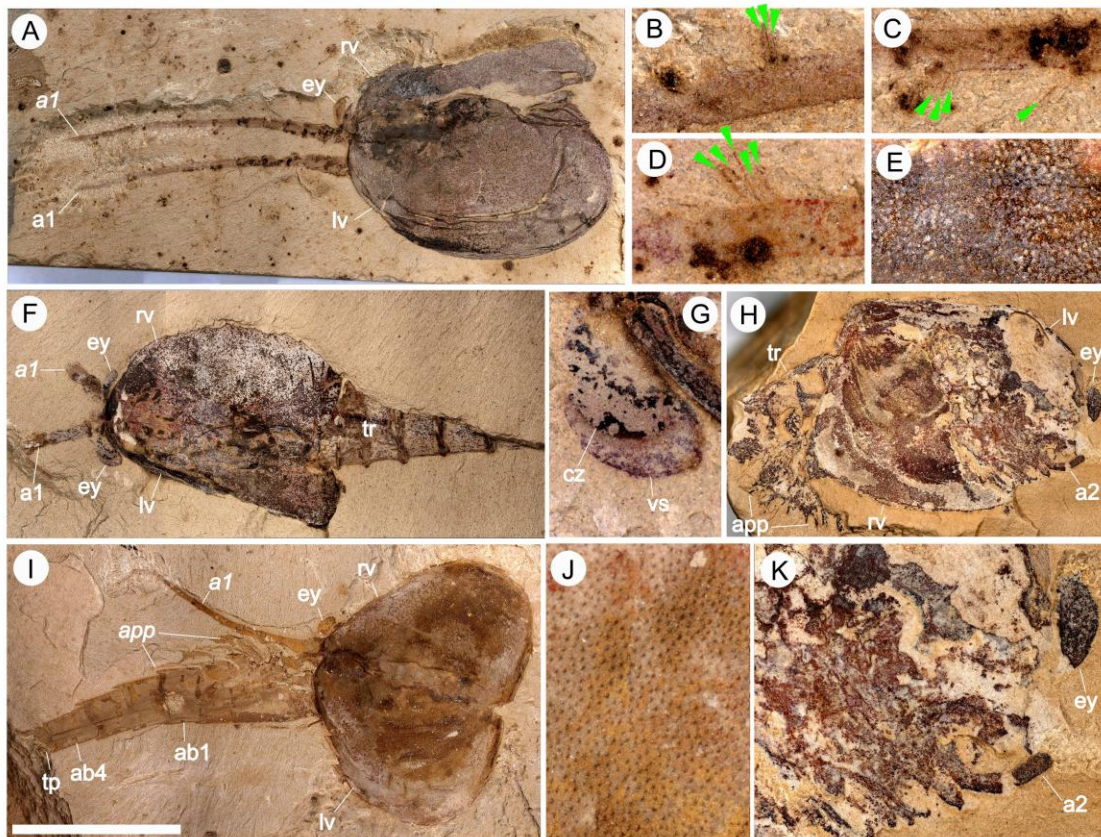
530 bar = 3.4 mm. (B) YKLP 13967a, left lateral view. Scale bar = 5.0 mm.

531 Abbreviations additional to fig. 1: s1-s12, head and thoracic segments. s1 is

532 the eye-bearing segment/anterior sclerite; the position of segments s1 and s2

533 is difficult to infer. Italics indicate a right-side appendage.

534



535

536 **Figure 3.** Photographs of *Chuandianella ovata*, showing morphological details.

537 (A-E) YKLP 16217a (cf. **Supplementary Figure 3**). (A) Dorsal view. Scale bar

538 = 8.3 mm. (B) Setae on inner surface of 7<sup>th</sup> podomere of left antenna. Scale

539 bar = 0.1 mm. (C) Setae on inner surface of 5<sup>th</sup> podomere of right antenna.

540 Scale bar = 1.6 mm. (D) Setae on inner surface of 5<sup>th</sup> podomere of left

541 antenna. Scale bar = 1.3 mm. (E) Pits on carapace surface. Scale bar = 1.0

542 mm. (F,G) YKLP 16238a, specimen depicted in **Figure 1f**. (F) dorsal view.

543 Scale bar = 8.4 mm. (G) Visual surface of the left eye. Scale bar = 1.6 mm.

544 (H,K) YKLP 16259, a laterally compressed specimen with anterior part of right

545 valve missing, exposing the anterior appendages. Posterior part of trunk is also

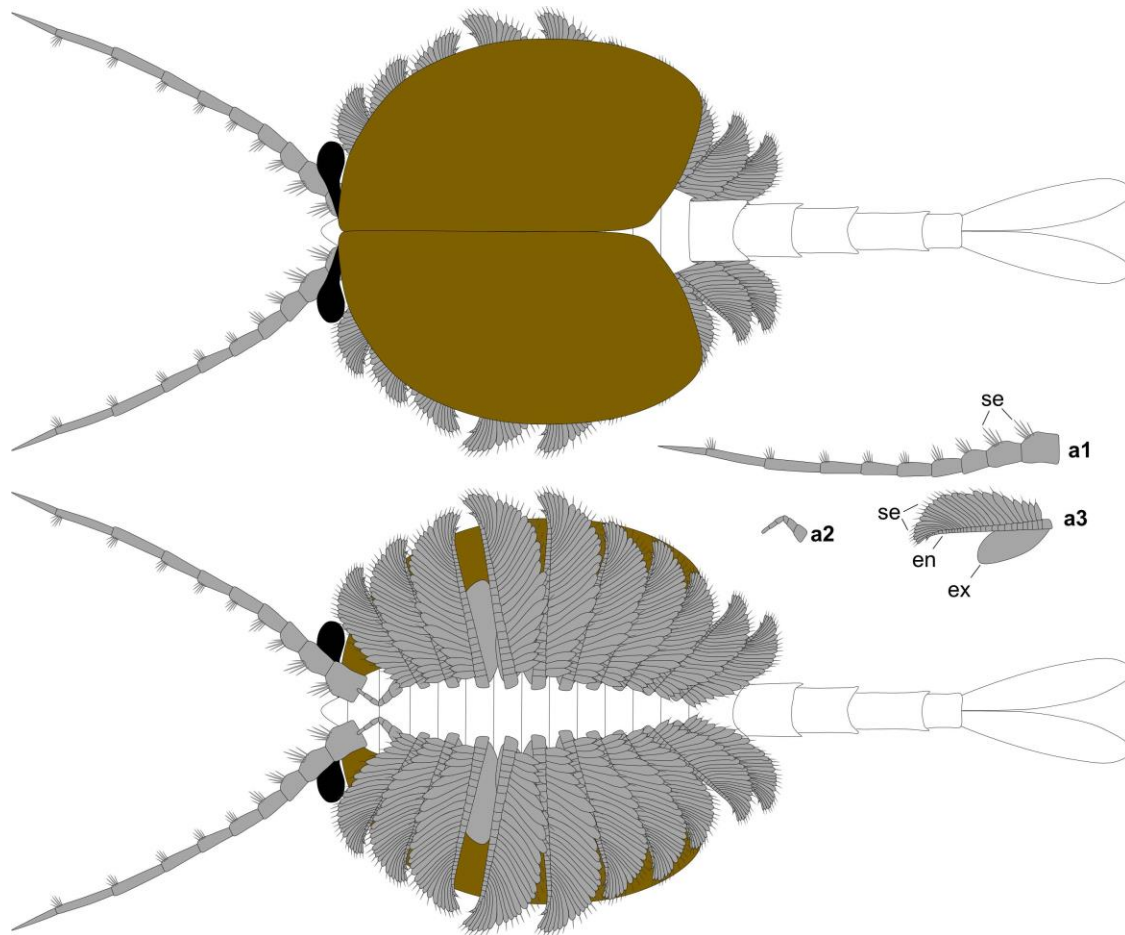
546 missing. (H) Overview. Scale bar = 6.0 mm. (K) Detailed view of anterior part,

547 showing position and morphology of a2. Scale bar = 2.4 mm. (I,J) YKLP

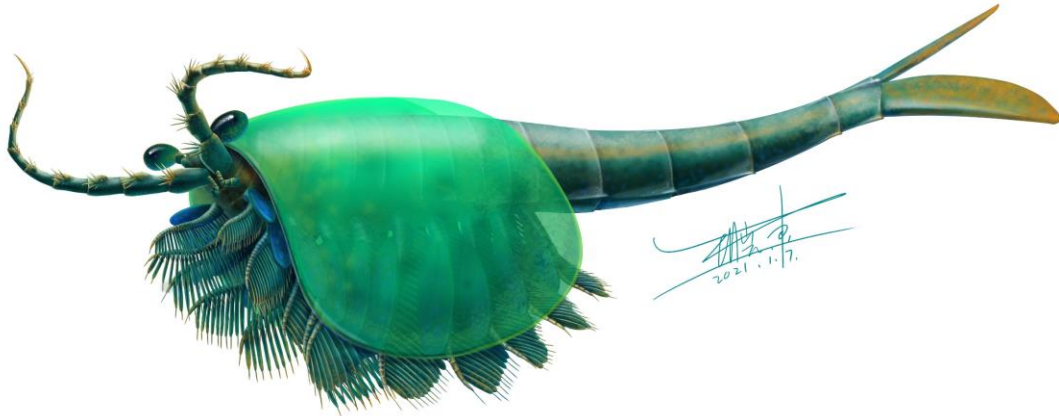
548 16239, specimen depicted in **Figure 1g,h**. (I) Dorsal view with trunk reflexed



549 so that it appears to emerge from anterior end of carapace. Scale bar = 8.8  
550 mm. (J) Pits on carapace surface. Scale bar = 0.9 mm. Abbreviations  
551 additional to figs 1, 2: app, appendage; vs, visual surface. Italics indicate a  
552 right-side appendage.  
553



554  
555 **Figure 4.** Reconstruction of *Chuandianella ovata*. Upper: dorsal view. Lower:  
556 ventral view. Right middle: isolated appendages a1-a3. Not to scale.  
557 Abbreviations as in figs 1-3.  
558



559

560 **Figure 5.** Reconstruction of *Chuandianella ovata* *in vivo*.

561