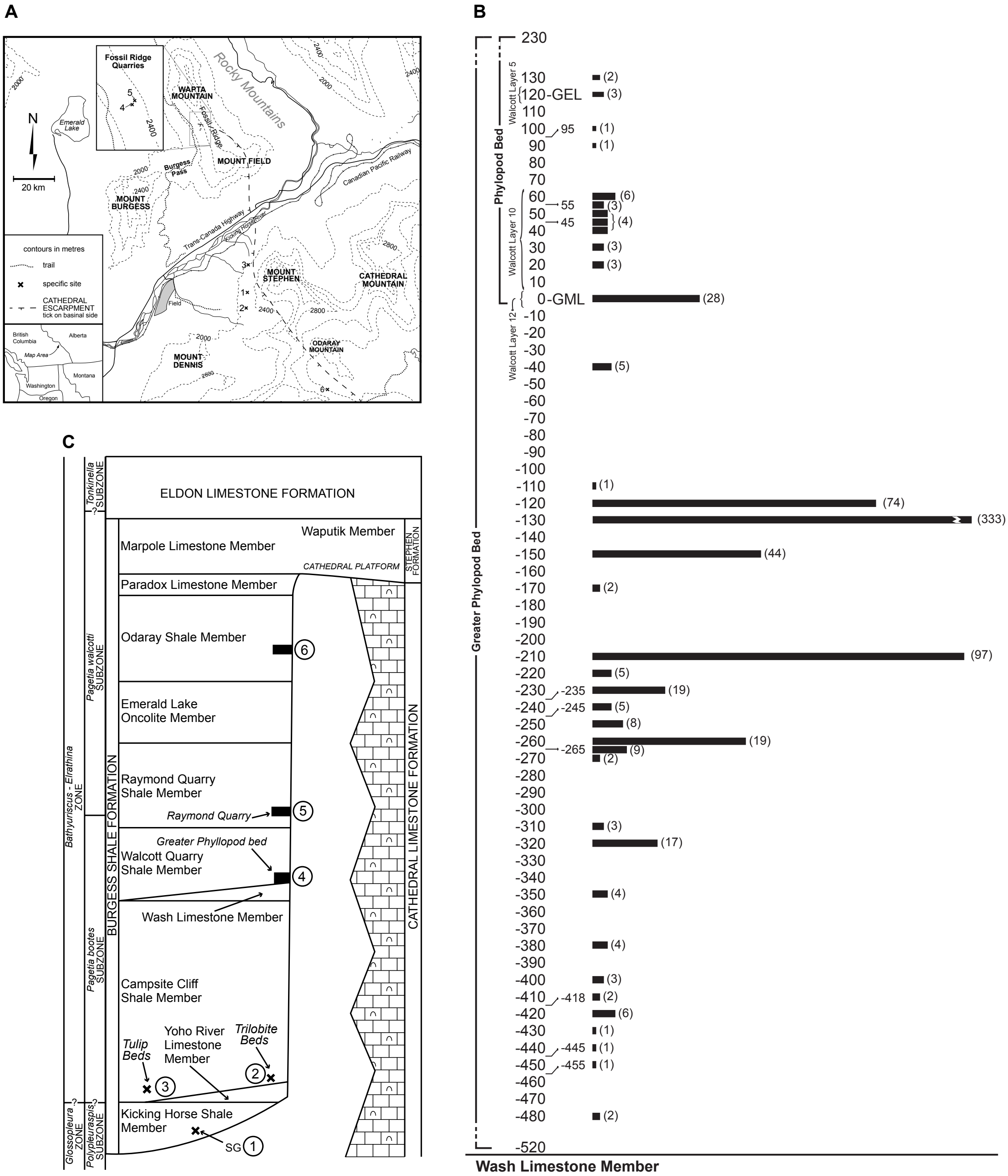
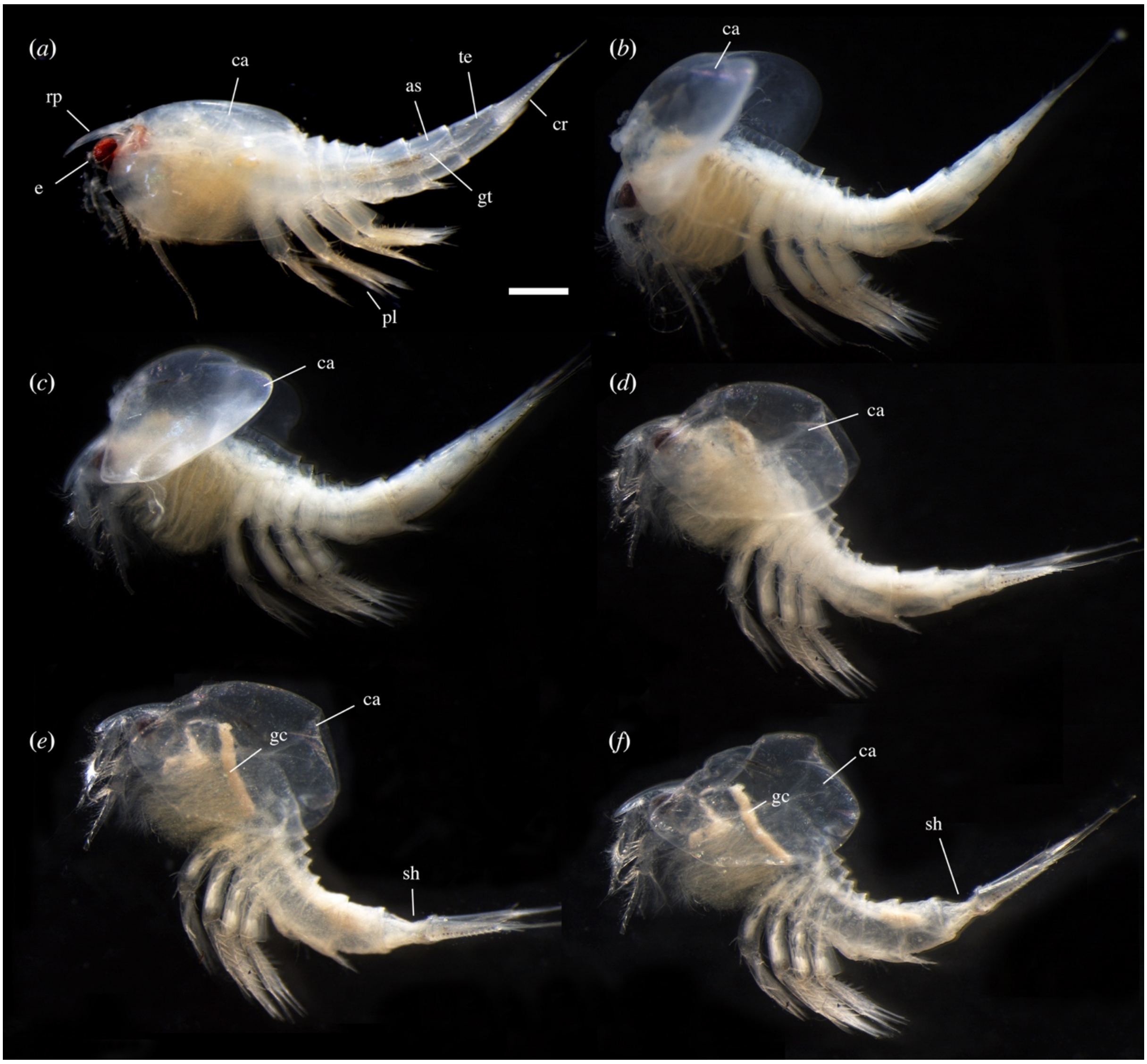
# *Waptia fieldensis* Walcott, a mandibulate arthropod from the middle Cambrian Burgess Shale

Jean Vannier, Cédric Aria, Rod S. Taylor and Jean-Bernard Caron

## Electronic supplementary material S1-S20, 22




**Electronic supplementary material S1.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; geographic and stratigraphic distribution. (*a*) Locality map; 1, SG locality, Mount Stephen; 2, ST locality, Trilobite Beds; 3, Tulip Beds (S7) locality; 4, Walcott Quarry (Greater Phyllopod Bed); 5, Raymond Quarry. (*b*) Detailed vertical distribution within the Greater Phyllopod Bed; levels in cm above and below the base of the Walcott Quarry; GEL, Great *Eldonia* Layer; GML; Great *Marrella* Layer. (*c*) Stratigraphic occurrences of *Waptia fieldensis* within the Burgess Shale ("Thick" Stephen) Formation.




**Electronic supplementary material S2**. *Nebalia bipes* (Crustacea, Malacostraca, Leptostraca); decay experiments. (*a-f*) Live specimen in lateral view and 2, 4, 8, 14 and 21 days after death (kept in a petri dish filled with sea water, no sediment, temperature 20°C). Abbreviations are as follows: as, abdominal segment; ca, carapace; cr, caudal ramus; e, eye; gc, gut content; gu, gut; pl, pleopod; rp, rostral plate; sh, shrinkage; te, telson. Scale bar: 1 mm.

**Electronic supplementary material S3.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; rock slab (ROMIP 56421) from level -120 cm (Greater Phyllopod Bed) showing three complete specimens on the same bedding plane. Note the specimen in the middle shows clear sign of disarticulation of the carapace. Photograph taken under cross-polarized light. Scale bar: 1 cm**.**

**Electronic supplementary material S4**. *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; Synonymy list.

# *Waptia fieldensis* Walcott, 1912

1912 *Waptia fieldensis*; Walcott [1], p. 152-4, 156-9, 161, 163, 181-182, 214-215, 220-221; Pl. 27, figs 4, 5.
1912 *Burgessia bella*; Walcott [1]; p. 177, 180; Pl. 30, fig. 4 (USNM 57679, erroneously recorded as USNM 57680).
1919 *Waptia*; Crampton [2], p. 155-156.
1920 *Waptia fieldensis*; Raymond [3], p. 108-109.
1925 *Waptia fieldensis*; Fedotov [4], p. 386, 389.
1928 *Waptia fieldensis*; Henriksen [5], p. 2, 10, 13-14.
1930 *Waptia*; Beurlen [6], p. 501.
1931 *Waptia fieldensis*; Walcott ([7], posthumous), p. 20-24, 43-44; figs 6-7. (reconstructions); Pl. 18, figs 2-5, Pl. 19, figs 1-4; Pl. 20, figs 1-3; Pl. 21, fig. 2.
1931 *Waptia circularis*; Walcott ([7], posthumous), p. 24, 45; Pl. 21, fig.3.
1933 *Waptia*; Størmer [8], p. 154, 156; fig. 2c.
1935 *Waptia*; Raymond [9], p. 214-217, 227.
1939 *Waptia fieldensis*; Størmer [10], p. 230-232, 233, 237, 267-268; figs 29g, 30d.
1944 *Waptia fieldensis*; Størmer [11], p. 87, 94, 95, 97, 99-101, 106, 107, 109, 113, 123, 124, 130; fig 19, 7-8.
1946 *Waptia*; Linder [12], p. 20-21.
1949 *Waptia*; Vandel [13], p. 88, 140.
1953 *Waptia*; Dechaseaux [14], p. 37-39, 43; fig. 11.
1953 *Waptia fieldensis*; Heldt [15], p. 177-180; Pl. 21, figs 2-4.
1954 *Waptia*; Burton [16], p. 108, 125, 126; fig. 45.
1956 *Waptia*; Caster and Brooks [17], p. 180.
1958 *Waptia fieldensis*; Tiegs and Manton [18], p. 291-293, 313-314, 316; fig. 6c.
1959 *Waptia*; Størmer [19], p. O23-28, O32, O33 (Treatise on Invertebrate Paleontology); fig. 21, 6-8.
1960 *Waptia fieldensis*; Novozhilov [20], p. 198, 199, 207; fig. 441.
1962 *Waptia fieldensis*; Rolfe [21], p. 5.
1970 *Burgessia bella*; Simonetta [22], Pl. 28, fig. 4.
1974 *Waptia fieldensis*; Whittington [23], p. 15, 19-20; Pl. 27, figs 3, 4.
1975 *Waptia*; Hessler and Newman [24], p. 448-449; fig. 10B.
1975 *Waptia fieldensis*; Hughes [25], p. 415, 418, 419.
1975 *Waptia fieldensis*, Simonetta and Delle Cave [26], p. 10, 34; Pl; 5, figs 5a, b (reconstructions); Pl. 41, figs 1-11; Pl. 42, figs 1-15; Pl. 43, figs 1-7.
1977 *Waptia fieldensis*; Hughes [27], p. 15.
1979 *Waptia*; Conway Morris and Whittington [28], p. 111.
1979 *Waptia fieldensis*; Doveton [29], p. 215-226; Pl. 1, figs 2, 4-5.
1980 *Waptia fieldensis*; Tasch [30], p. 482-485, 491; fig. 10.4F.
1983 *Waptia*; McKenzie [31], p. 36 ; table 1.
1980 *Waptia fieldensis*; Bergström [32], p. 10.
1982 *Waptia fieldensis*; Hughes *in* Conway Morris *et al.* [33], p. 18; fig. K (lectotype, left specimen).
1982 *Waptia*; Whittington [34], p. 19; figs 2-10.
1983 *Waptia fieldensis*; Briggs [35], p. 5-6, 12, 15-18; figs 2A, 3, 4; table 2.
1984 *Waptia*; Dahl [36], p. 68, 74.
1985 *Waptia fieldensis*; Briggs and Whittington [37], p. 150, 152, 155-156, 158; fig. 2i; table 1.
1985 *Waptia fieldensis*; Whittington [38], p. 45, 65-66, 68, 104, 123, 138; figs 4.51, 5.1.
1986 *Waptia*; Conway Morris [39], p. 439; fig. 7c.
1986 ?*Waptia*; Schram [40], p. 33; table 2-2.
1989 *Waptia*; Briggs and Fortey [41], p. 242; fig. 1.
1989 *Waptia*; Gould [42], p. 25, 72-73, 121, 138, 219, 221; figs 2.6, 3.7.
1990 *Waptia*; Briggs [43], p. 25, 33, 34; fig. 3.
1991 *Waptia*; Delle Cave and Simonetta [44], p. 190, 228, 229; fig. 25D1-2.
1992 *Waptia*; Bergström [45], p. 288, 289, 290; figs 2, 3.
1992 *Waptia*; Briggs *et al.* [46], p. 1671, 1672; figs 1-3.
1993 *Waptia*; Briggs *et al.* [47], p. 39-42; figs 1,2; tables 1, 2.

1994 *Waptia fieldensis*; Briggs *et al*. [48], p. 157, 158, figs 110-112 (reconstruction).
1994 *Waptia*; Wills *et al*. [49], p. 106, 109, 111, 115; figs 4, 7, 8, 11.
1995 *Waptia*; Bousfield [50], p. 24.
1997 *Waptia fieldensis*; Chen and Zhou [51], p. 67-69.
1997 *Waptia*; Erwin *et al*. [52], p. 128-129; fig. 2.
1997 *Waptia fieldensis*; Hou and Bergström [53], p. 41-42, 105, 111.
1997 *Waptia*; Wills [54], p. 197, 198, 201; fig. 15.4.
1997 *Waptia*; Wills *et al*. [55], p. 59, 60, 63; figs 6.1, 6.2, 6.5.
1998 *Waptia*; Conway Morris [56], p. 173, 174, 195, 288-291; figs 6.8-6.11.
1998 *Waptia*; Schram and Hof [57], p. 238-240, 265, 283, 284; fig. 6.3; table 6.3 (p. 283, cladistic analysis).
1998 *Waptia*; Fletcher and Collins [58], p. 428.
1998 *Waptia*; Wills *et al*. [59], p. 46, 71-74, 80, 83, 84, 86, 87; figs 2.1(d), 2.2, 2.3, 2.5, 2.6, 2.7; table 2.1 (cladistic analysis).
1999 *Waptia fieldensis*; Waloszek [60], p. 21.
1999 *Waptia fieldensis*; Hou [61], p. 111, 114.
2000 *Waptia fieldensis*; Garcia-Bellido [62], p. 145; fig. 5.
2000 *Waptia*; Bengtson [63], p. 5; fig. 2.
2001 *Waptia*; Budd [64], p. 410; fig. 18.1.
2001 *Waptia fieldensis*; Donovan and Lewis [65], p. 232; fig. 1a.
2002 *Waptia fieldensis*; Taylor [66], p. 113, 117, 120; fig. 11A.
2002 *Waptia fieldensis;* Taylor and Collins [67], abstract.
2004 *Waptia fieldensis;* Hou *et al*. [68], p. 136.
2004 *Waptia*; Schwab [69], p. 164.
2005 *Waptia fieldensis*; Parker [70], p. 2; fig. 1.
2005 *Waptia fieldensis*; Davidson and Erwin [71], p. 797; fig. 1b.
2006 *Waptia fieldensis*; Caron and Jackson [72], p. 456, 458; fig 5; Supplementary Data 5F.
2007 *Waptia fieldensis*; Zhang and Shu [73], p. 1414; fig. 4.6.
2008 *Waptia fieldensis*; Caron and Jackson [74]; figs 11, 12; table 1; Appendix B, C, D, F.
2008 *Waptia fieldensis*; Liu and Shu [75], p. 353, 360.
2008 *Waptia* cf. *fieldensis*; Briggs *et al*. [76]; p. 250, 251; fig. 12.
2009 *Waptia*; Collins [77]; p. 16, 25.
2009 *Waptia*; Hou *et al*. [78]; p. 957, 958.
2009 *Waptia fieldensis*; Caron [79], p. 74; fig. 18; table 1.
2009 *Waptia fieldensis*; Strausfeld [80] (abstract).
2011 *Waptia fieldensis*; Strausfeld [81]; p. 157-167; figs 1-7 (USNM 83948j, erroneously recorded as USNM 57682 in fig. 4; reconstructions in figs 1, 4 ), table 1.
2012 *Waptia fieldensis*; Strausfeld [82]; p. 588-592, fig. 12.10 (reconstruction).
2012 *Waptia fieldensis*; Vannier *et al*. [83], p. 92 (abstract).
2016 *Waptia fieldensis*; Strausfeld [84]; p. 173-184; figs 1-6 (reconstructions in figs 1, 2, 6); suppl. fig. 1.
2016 *Waptia fieldensis*; Caron and Vannier [85], p. 1-6; figs 1, 2, 3A; suppl. figs 1-3.

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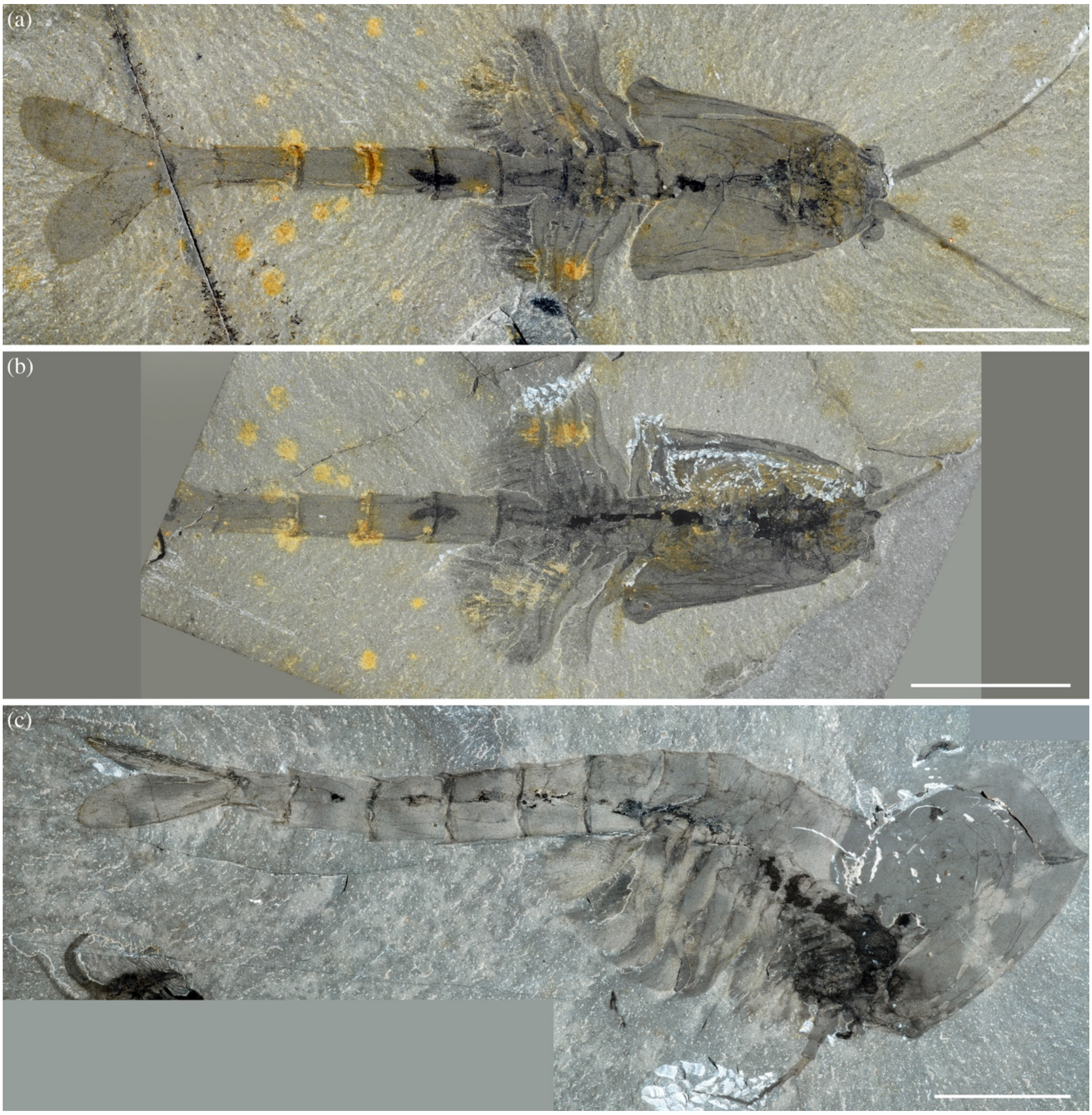
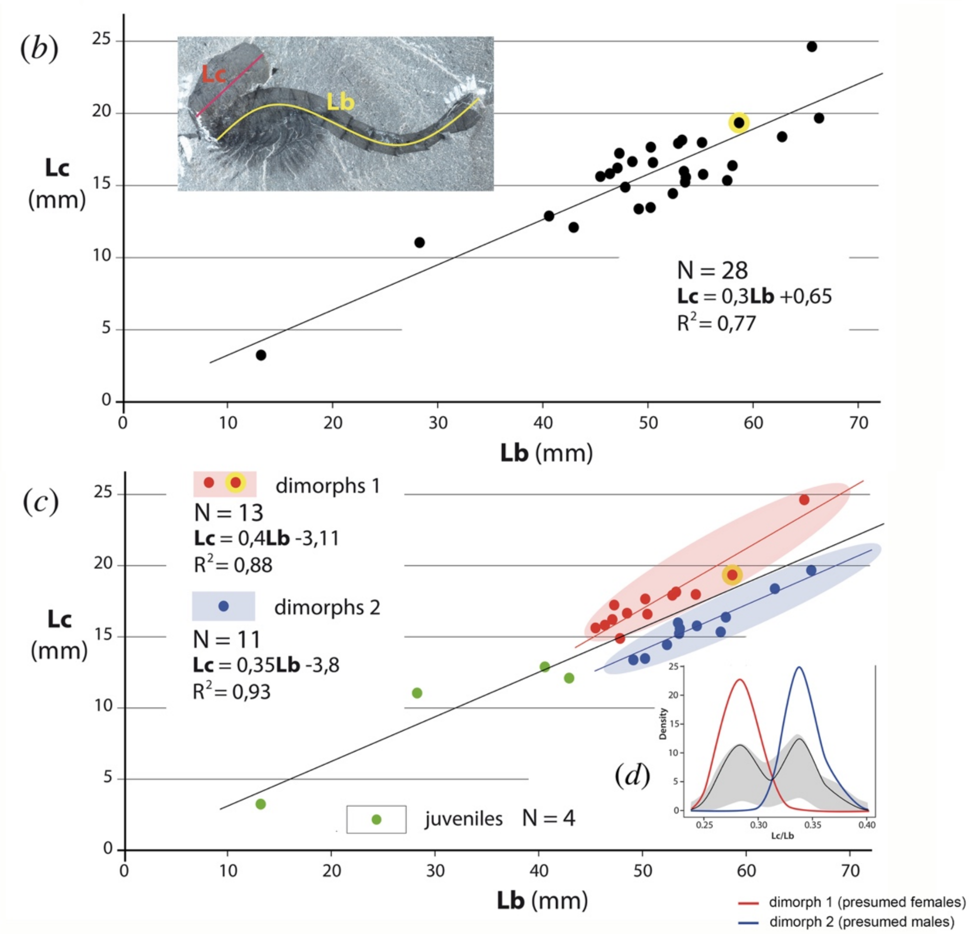



**Electronic supplementary material S5**. *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; type specimens. (*a, b*) USNM 57681, lectotype (designated by Hughes *in* Conway Morris (1982), part and counterpart, preserved in ventral view, post-antennular anterior appendages missing. (*c*) USNM 57682, preserved in lateral view, carapace displaced forwards. Scale bar: 1 cm.

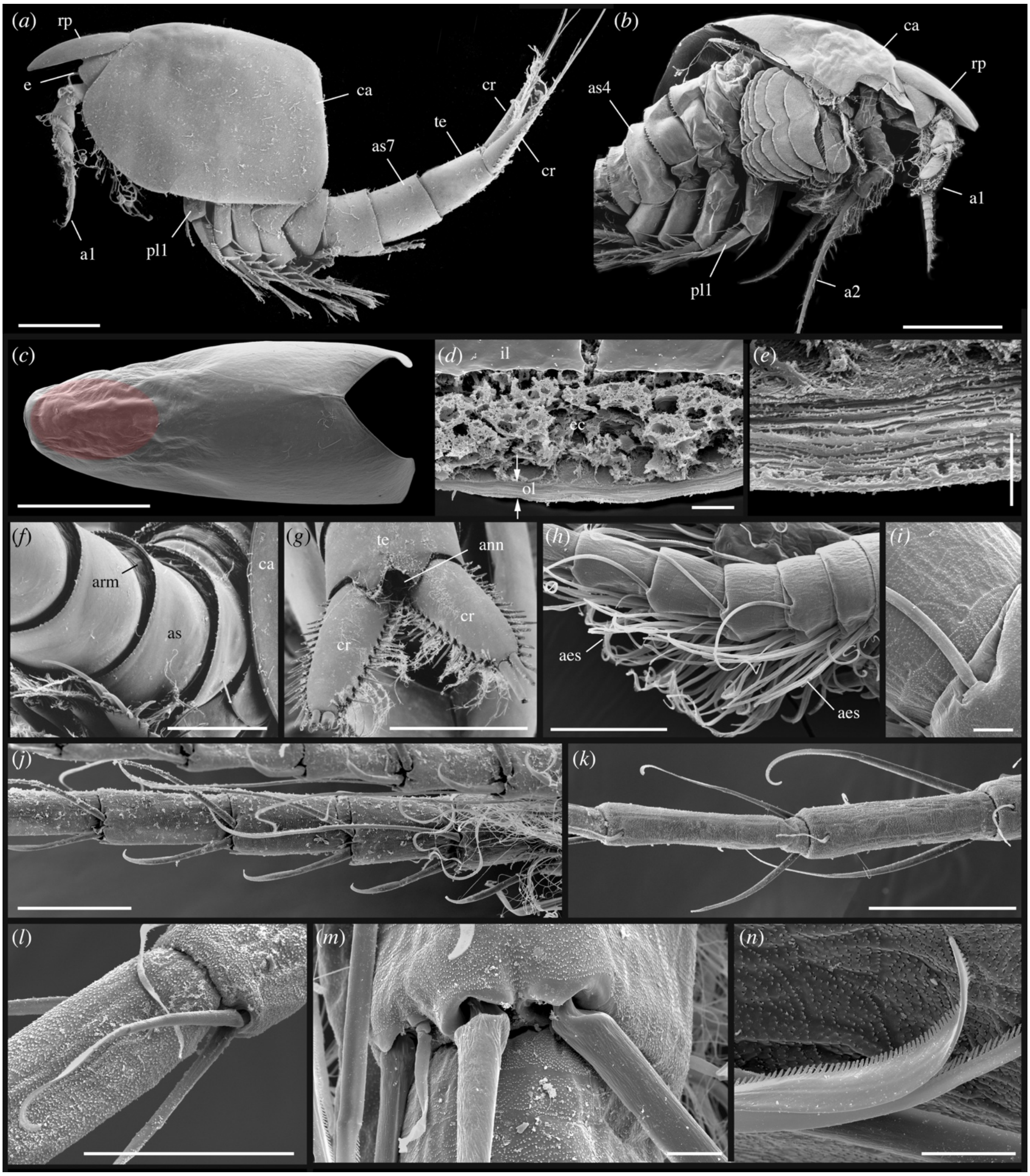
Reference: Conway Morris S, Whittington HB, Briggs DEG, Hughes CP, Bruton DL. 1982 Atlas of the Burgess Shale. Palaeontological Association, London.

(*a*)

| Coll. N° | field N° | origin | Fig. | Lb (mm) | Lc (mm) | Lc/Lb | stage | shape | view | remark |
|---|---|---|---|---|---|---|---|---|---|---|
| ROMIP 56947 | 931616 | WQ (-130) | 12e, 18h, S11 | 47.13 | 16.12 | 0.34 | dim 1 | curved | lateral | |
| ROMIP 63357 | | WQ (+45) | see ref (*), Fig. 2a, b | 55.69 | 18.14 | 0.32 | dim 1 (eggs) | curved | lateral | FEMeggs |
| ROMIP 64287 | 910635 | RQ | 4p | 52.43 | 14.36 | 0.27 | dim 2 | curved | lateral | |
| ROMIP 64282 | 930646 | WQ (Talus) | 1g; 26d, e | 43.43 | undet. | undet. | juvenile | straight | ventral | |
| ROMIP 64293 | 940305 | WQ(-130) | 14e; 24a, b | 48.56 | 16.56 | 0.34 | dim 1 | straight | ventral | |
| ROMIP 56421 | 940677 | WQ(-130) | 1c; 14c, d; S3 | 57.66 | 15.31 | 0.26 | dim 2 | curved | lateral | |
| ROMIP 64289 | 940874 | WQ(-130) | 6i | 50.24 | 13.40 | 0.27 | dim 2 | curved | lateral | |
| ROMIP 64281 | 941470 | WQ(-130) | 1e, 6g, 18i; S12b, d, e; S17e | 42.96 | 12.05 | 0.28 | juvenile | curved | lateral | |
| ROMIP 64295 | 950242 | WQ (Talus) | 2; 15a, b; 18a | 42.70 | undet. | undet. | juvenile | straight | ventral | |
| ROMIP 64296 | 950542 | WQ(-120) | 26a | 40.34 | undet. | undet. | juvenile | straight | ventral | |
| **USNM 57681a** | | | **1a, 19c, 26b; S5a,b** | **55.26** | **15.65** | **0.28** | dim 2 | **straight** | **ventral** | **LT** |
| USNM 57682 | | | S5c, S17f | 66.30 | 19.59 | 0.29 | dim 2 | curved | lateral | |
| USNM 83948a | | | unfigured | 53.48 | 15.84 | 0.29 | dim 2 | curved | lateral | |
| USNM 83948b | | | unfigured | 62.75 | 18.23 | 0.29 | dim 2 | curved | lateral | |
| USNM 83948f | | | unfigured | 47.90 | 14.78 | 0.31 | dim 1 | curved | lateral | |
| USNM 83948k | | | 18f | 48.82 | undet. | undet. | dim undet. | straight | ventral | |
| USNM 83949 | | | unfigured | 46.35 | 15.72 | 0.34 | dim 1 | curved | lateral | |
| USNM 114259 | | | S17a-d | 58.06 | 16.32 | 0.28 | dim 2 | curved | lateral | |
| USNM 139214 | | | 1b, 12h, 14h | 52.91 | 17.85 | 0.34 | dim 1 | curved | lateral | |
| USNM 165229 | | | 19b | 13.15 | 3.22 | 0.24 | juvenile | straight | dorsal | |
| USNM 189277 | | | unfigured | 47.35 | 17.10 | 0.36 | dim 1 | curved | lateral | |
| USNM 267750 | | | unfigured | 50.31 | 17.56 | 0.35 | dim 1 | curved | lateral | |
| USNM 268057 | | | unfigured | 65.56 | 24.54 | 0.37 | dim 1 | curved | lateral | |
| USNM 268146 | | | unfigured | 53.20 | 18.00 | 0.34 | dim 1 | curved | lateral | |
| USNM 268270 | | | 1d, 14i; 24g, h | 50.53 | 16.47 | 0.32 | dim 1 | curved | lateral | |
| USNM 268338 | | | 19a | 28.25 | 10.99 | 0.39 | juvenile | curved | lateral | |
| USNM 275504 | | | 16a-f; 18b; S14a, b | 53.68 | 15.41 | 0.29 | dim 2 | straight | ventral | |
| USNM 529131 | | | 1f | 40.62 | 12.80 | 0.31 | juvenile | curved | lateral | |
| USNM 529138 | | | unfigured | 49.18 | 13.26 | 0.27 | dim 2 | curved | lateral | |
| USNM 529144 | | | unfigured | 45.51 | 15.54 | 0.34 | dim 1 | curved | lateral | |
| USNM 529189 | | | 6f | 58.68 | 19.28 | 0.33 | dim 1 | curved | lateral | |
| USNM 940677 | | | unfigured | 53.68 | 15.28 | 0.28 | dim 2 | curved | lateral | |



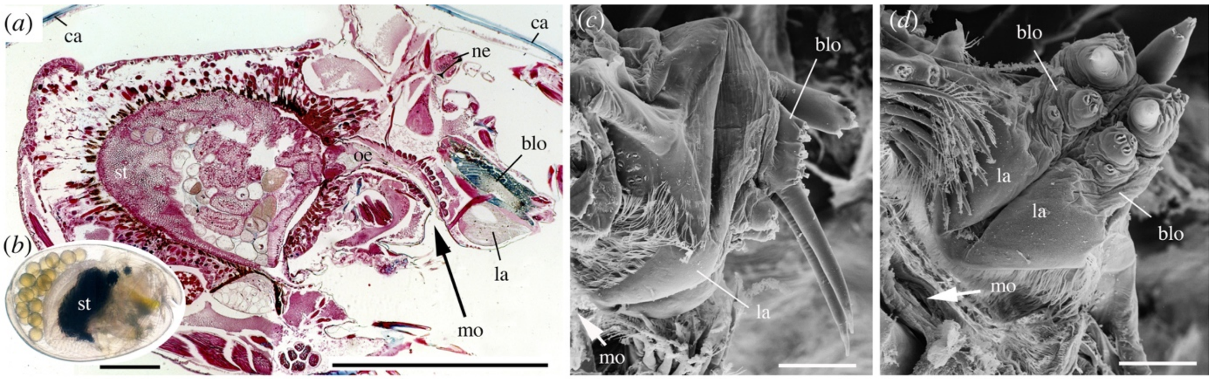

**Electronic supplementary material S6.** *Waptia fieldensis* Walcott, 1912 [10] from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; measurements of body and carapace length (Lb and Lc, respectively). (*a*) Data. (*b, c*) Lc to Lb ratio in 28 complete specimens. (*d*) Kernel density analysis of measured subadult and adult specimens of *Waptia fieldensis* Walcott, 1912. The black curve is the density of the whole data, showing clear bimodality, the red curve is the density of the extracted female data, and the blue curve is males. The grey area is the bootstrapped reference band calculated from female and male data, and indicates where a density estimate of the data would lie if it was normally distributed. Abbreviations are as follows: dim 1, assumed dimorphic specimens of type 1 (presumably females; red dots and line); dim 2, assumed dimorphic specimens of type 2 (presumably males; blue dots and line); FEMeggs, female carrying eggs (red dot highlighted in yellow; see Caron and Vannier (2016)); LT, lectotype; RQ, Raymond Quarry; S, Supplementary figure; WQ, Walcott Quarry.
(*) Reference: Caron JB, Vannier J. 2016 *Waptia* and the diversification of brood care in early arthropods. *Current Biology* 26, 1-6.



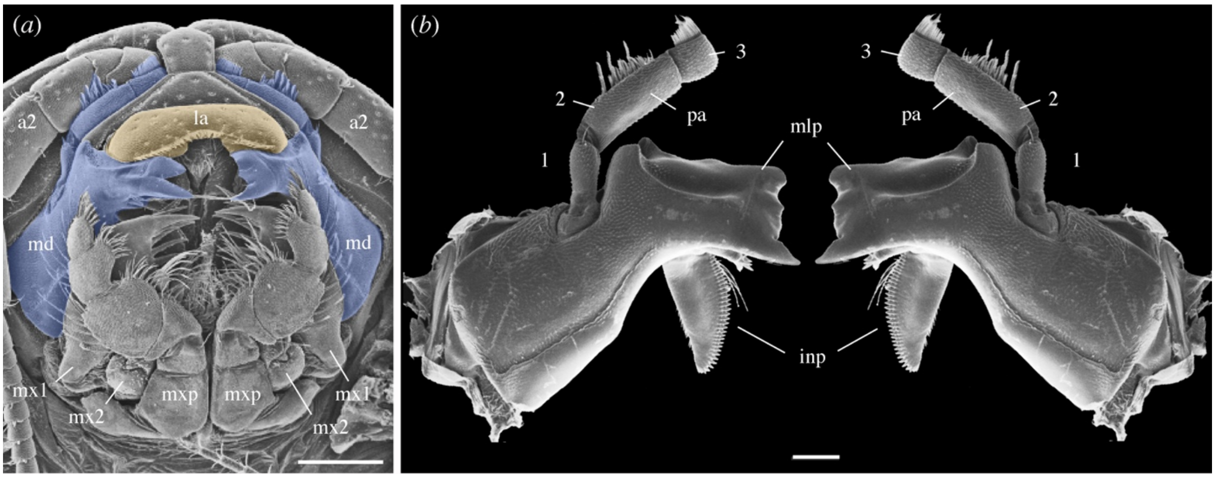

**Electronic supplementary material S7**. *Nebalia bipes* (Crustacea, Malacostraca, Leptostraca); general morphology. (*a*) Left lateral view. (*b*) Right lateral view, right lateral flap of carapace removed. (*c*) Dorsal view of carapace rostral plate removed. (*d*) Transverse section through carapace. (*e*) Transverse section through carapace outer lamella. (*f*) Telescopic abdominal segments in intermediate posterior view. (*g*) Ventral side of teson and caudal rami showing anus opening. (*h, i*) Antennule first antenna with bunches of aesthetascs, general view and detail. (*j, k*) Setation along second antenna. (*l, m*) Insertion of setae on second antenna. (*n*) Comb-like teeth near the tip of antennal setae. Approximate attachment area of carapace in red. Abbreviations are as follows: a1, first antenna, a2, second antenna; aes, aesthetasc; arm, arthrodial membrane; ann, anal notch; as, abdominal segment; ca, carapace; cr, caudal ramus; e, eye; ec, epidermal cells; il, carapace inner lamella; ol, carapace outer lamella; pl1, first pair of pleopod; rp, rostral plate; te, telson. Scale bars: 1 mm in *b*; 500 µm in *a, c, f, g*; 100 µm in *h, j, k*; 50 µm in *l*; 10 µm in *d, i, m, n*; 2 µm in *e*.


**Electronic supplementary material S8.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; ocular and inter-ocular regions. (*a, b*) USNM 83948j (part). (*c, d*) USNM 83948j (counterpart). (*e-g*) USNM 268199, general view and details of anterior median projection and eye. All images are photographs taken under cross-polarized light. Small white arrows indicate mineralized features interpreted as inter-ommatidial setae by Strausfeld (2016). Abbreviations are as follows: an, antennule; ca, carapace; e, eye; gu, gut; la, lamellate post-cephalothoracic appendage; mts, median triangular sclerite; pl, peduncular lobe. Scale bars: 5 mm in *a-e*; 1 mm in *g*; 500 µm in *f*.

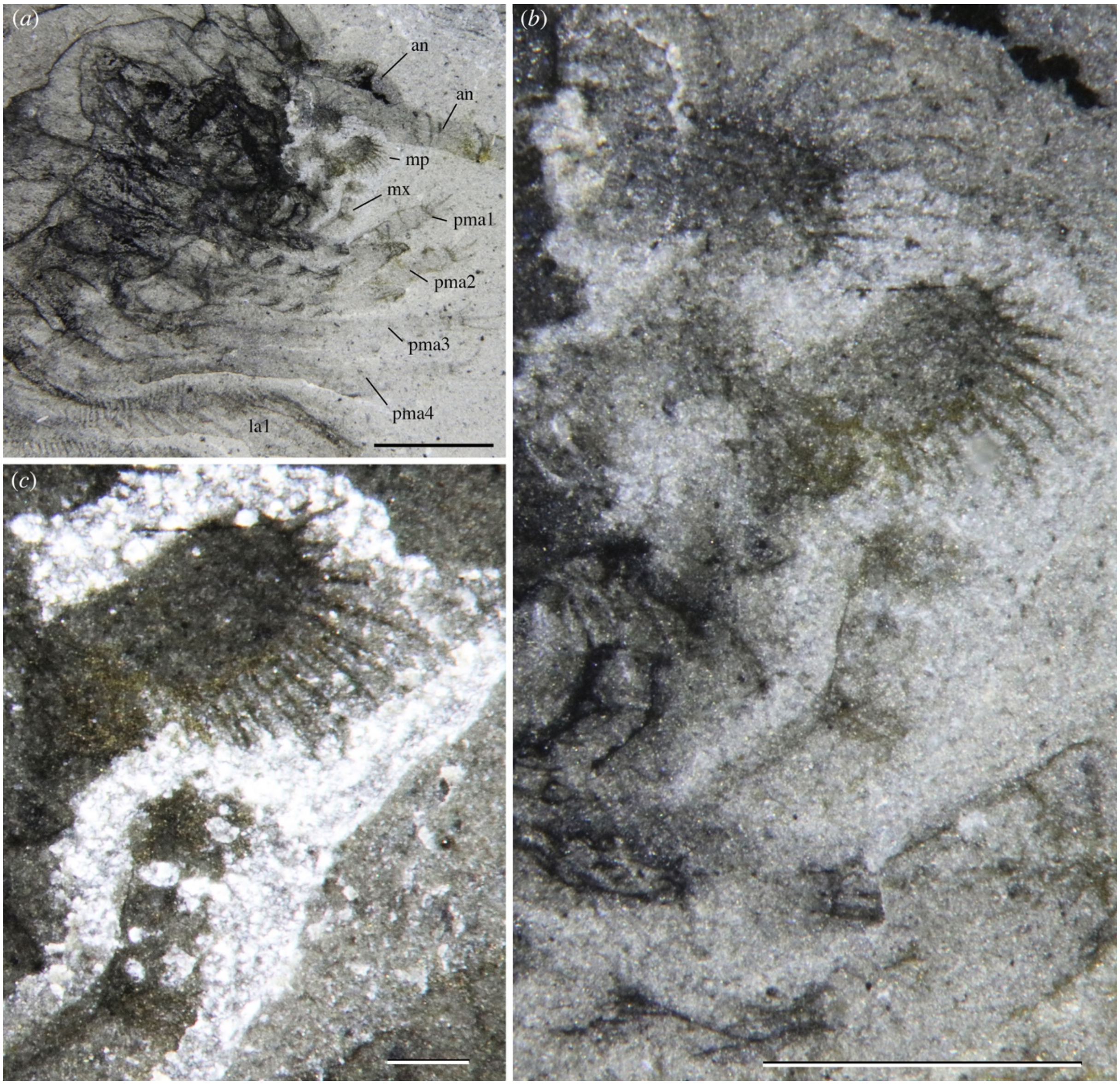
Reference: Strausfeld NJ. 2016 *Waptia* revisited, intimations of behaviours. *Arthropod Structure and Development* **45**, 173-184.



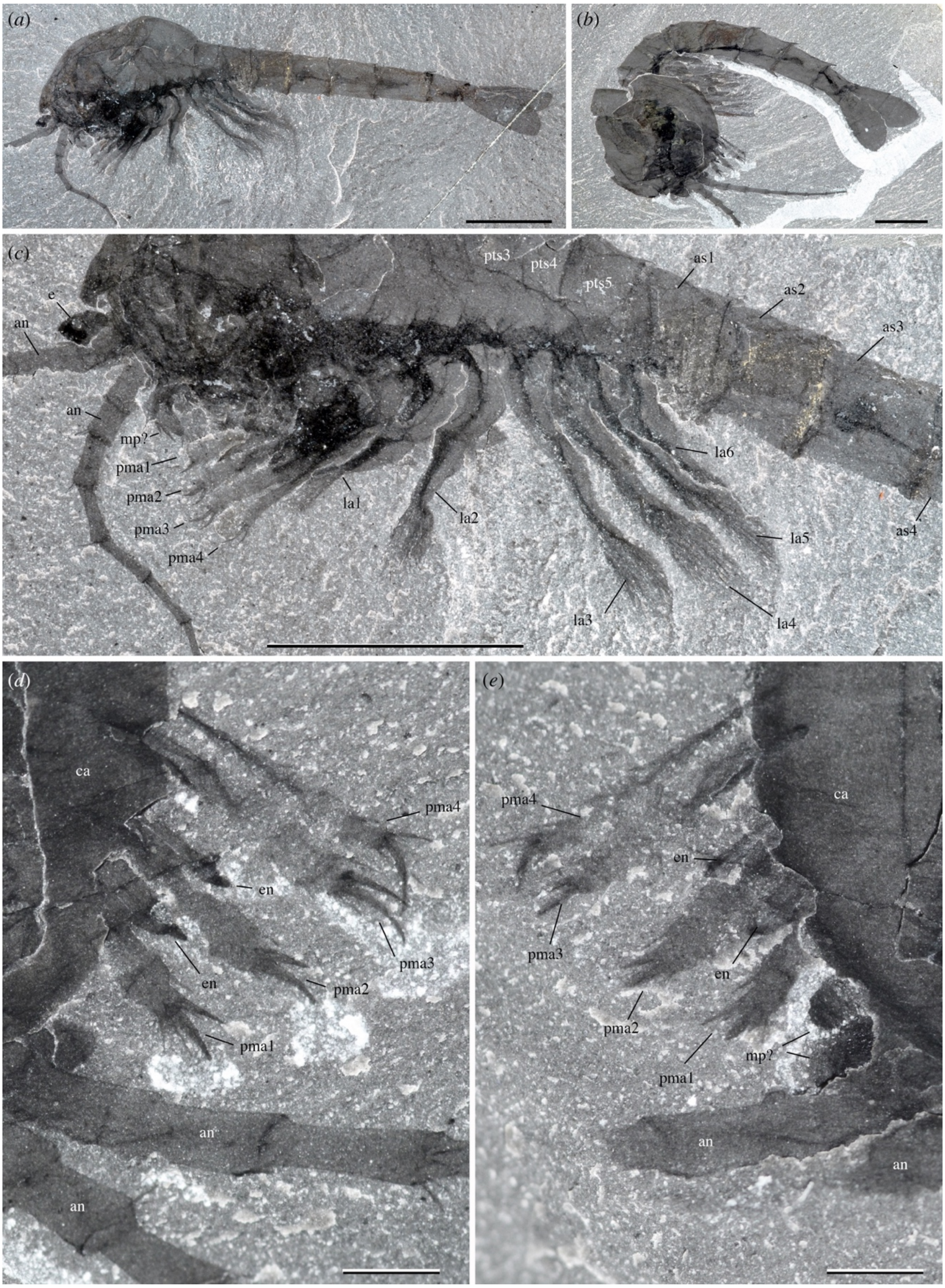

**Electronic supplementary material S9.** *Vargula hilgendorfii* (Crustacea, Ostracoda, Myodocopida) from Japan; details of labrum. (*a, b*) Stained sagittal paraffin section and lateral view of an adult female (translucent carapace). (*c, d*) Lateral and ventral view of the labrum (upper lip) showing its bilateral symmetry and paired structures; the labrum accommodates the bioluminescent organ. *c* and *d* are SEM images. Abbreviations are as follows: bio, bioluminescent organ; ca, carapace; la, labrum; mo, mouth; ne, nauplius eye; st, stomach. Scale bars: 1 mm in *a, b*; 100 µm in *c, d*.



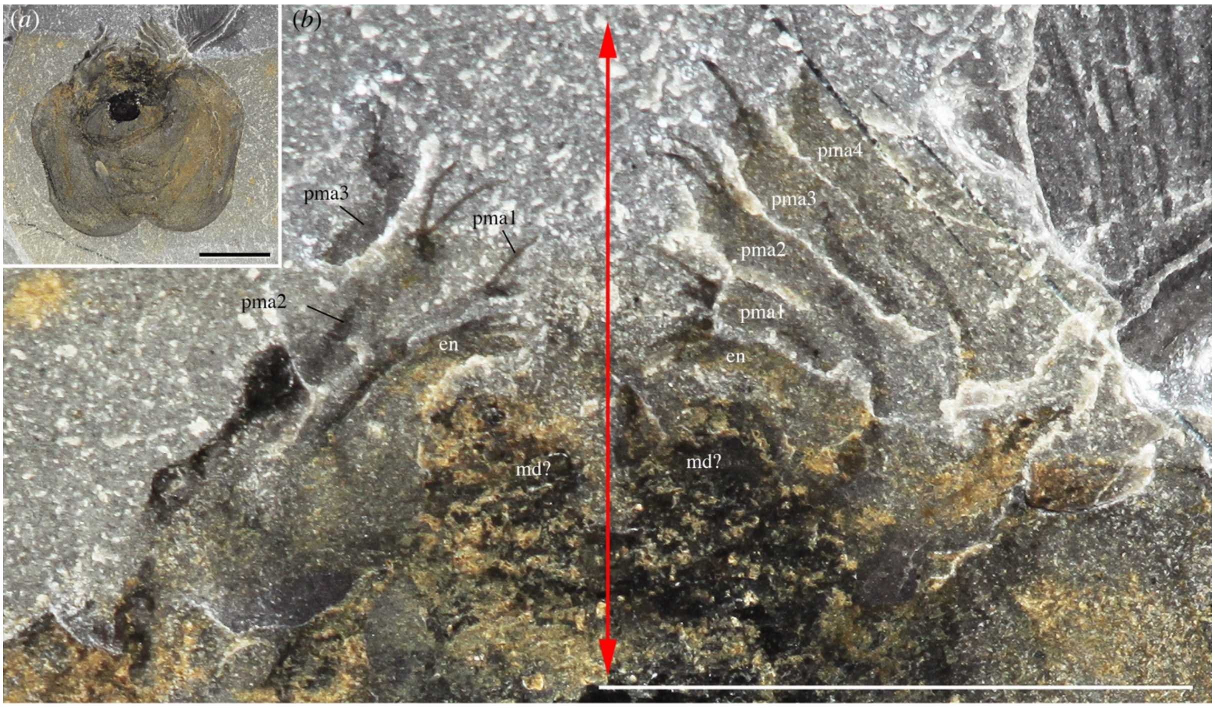

**Electronic supplementary material S10**. *Cirolana harfordi* (Crustacea, Isopoda), mouth parts. (*a*) General ventral view of cephalic region. (*b*) Isolated left mandible and its mirror image. All SEM images (reproduced and adapted from Thomson (2013; figs 4A and 10B) with permission to JV from Wiley Publishers; courtesy M. Thomson). Mandibles in blue, labrum in yellow. Abbreviations are as follows: a2, second antenna; inp, incisor process; la, labrum; md, mandible; mlp, molar process; mx, maxillule; mx2, maxilla; mxp, maxilliped; pa, palp; 1-3: 1st to 3rd podomere of palp. Scale bars: 300 µm in *a*; 200 µm in *b*. Reference: Thomson M. 2013 Mouthparts and their setae of the intertidal isopod *Cirolana harfordi*. *Journal of Microscopy* **252**, 111-121.




**Electronic supplementary material S11.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; ROMIP 56947, mandibular palp and maxillule. (*a*) General view. (*b, c*) Details showing right and left mandibular palps fringed with numerous setae and part of the maxillule. All images are photographs taken under cross-polarized light. Abbreviations are as follows: an, antenna; la1, 1st lamellate post-cephalothoracic appendage; mp, mandibular palp; mx, maxillule; pma1-4, 1st to 4th post-maxillular cephalothoracic appendages. Scale bars: 1 mm in *a*; 500 µm in *b*; 100 µm in *c*.

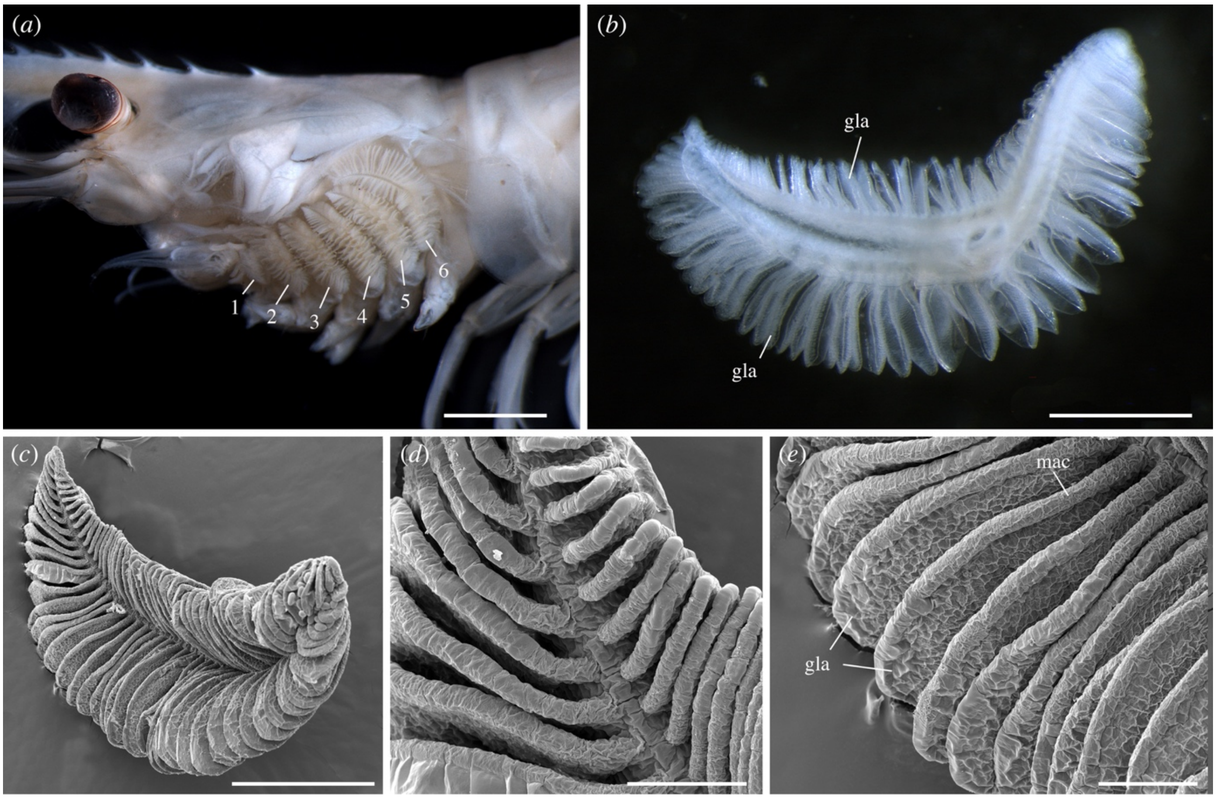



**Electronic supplementary material S12.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; post-maxillular cephalothoracic appendages. (*a, c*) USNM 139214, general view and details in lateral view. (*b, d, e*) ROMIP 64281, general view and details of appendages (part and counter part). All images are photographs taken under cross-polarized light. Abbreviations are as follows: an, antennule; as1-6, 1st to 6th abdominal segments; ca, carapace; e, eye; en, endite; la1-6, 1st to 6th lamellate post-cephalothoracic appendages; mp, mandibular palp; pma1-4, 1st to 4th post-maxillular cephalothoracic appendages; pts1-5, 1st to 5th thoracic segments. Scale bars: 1 cm in *a-c*; 5 mm in *b*; 1 mm in *d, e*.




**Electronic supplementary material S13.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; ROMIP 64385, post-maxillular appendages in intermediate frontal view. (*a, b*) General view of specimen and details of appendages converging towards the sagittal plane (double red arrow). Both images are photographs taken under cross-polarized light. Abbreviations are as follows: en, endite; md, mandible; pma1-4, 1st to 4th post-maxillular cephalothoracic appendages. Scale bars: 5 mm


**Electronic supplementary material S14**. *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada (*a, b*) USNM 275504, details of lamellate appendages; each coloured area corresponds to 10 annulations and lamellae. Both images are photographs taken under cross-polarized light. Abbreviations are as follows: la3-4, 3rd to 4th lamellate post-cephalothoracic appendage; so, socket. Scales bars: 5 mm.

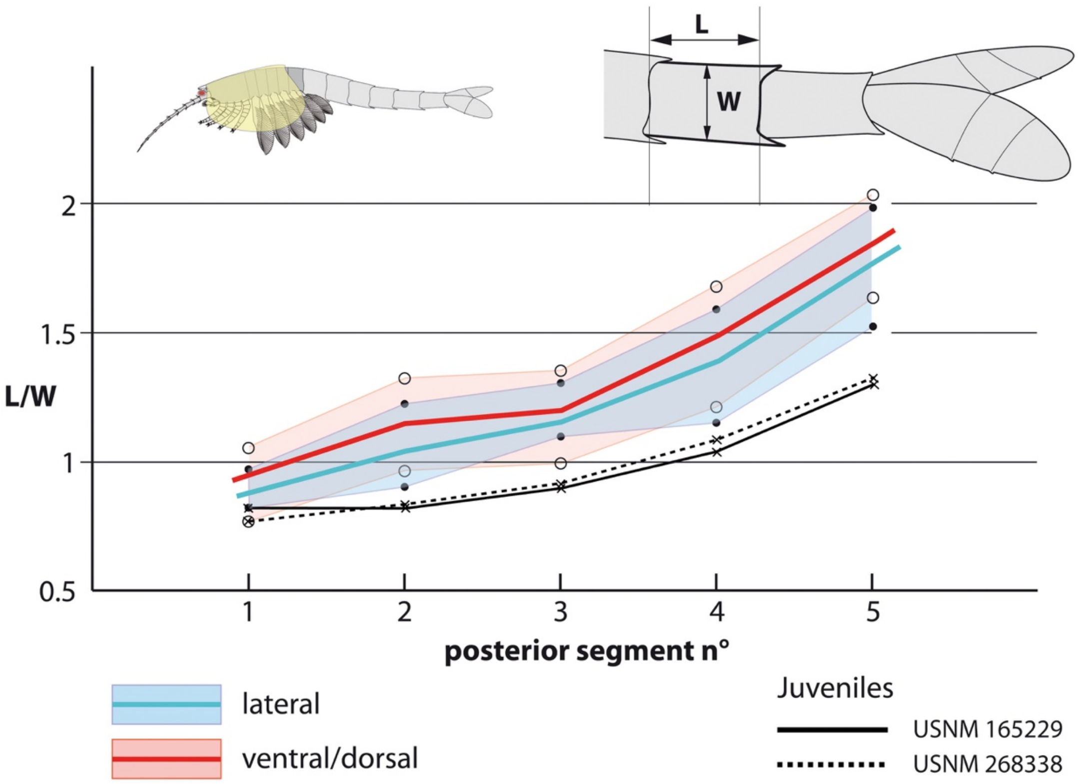



**Electronic supplementary material S15.** *Crangon crangon* (Crustacea, Decapoda, Caridea), phyllobranchiate gills. (*a*) Left side of carapace removed showing 6 gills attached to thoracic appendages. (*b*) Isolated gill. (*c-e*) General view of gill, details of axial structure and lamellae. Abbreviations are as follows: gla, gill lamella; mac, marginal canal. 1-6, 1st to 6th phyllobranchiate gills. *a, b* are light photographs; c-e are SEM images. Scale bars: 2 mm in *a*; 500 µm in *b, c*; 100 µm in *d, e*.

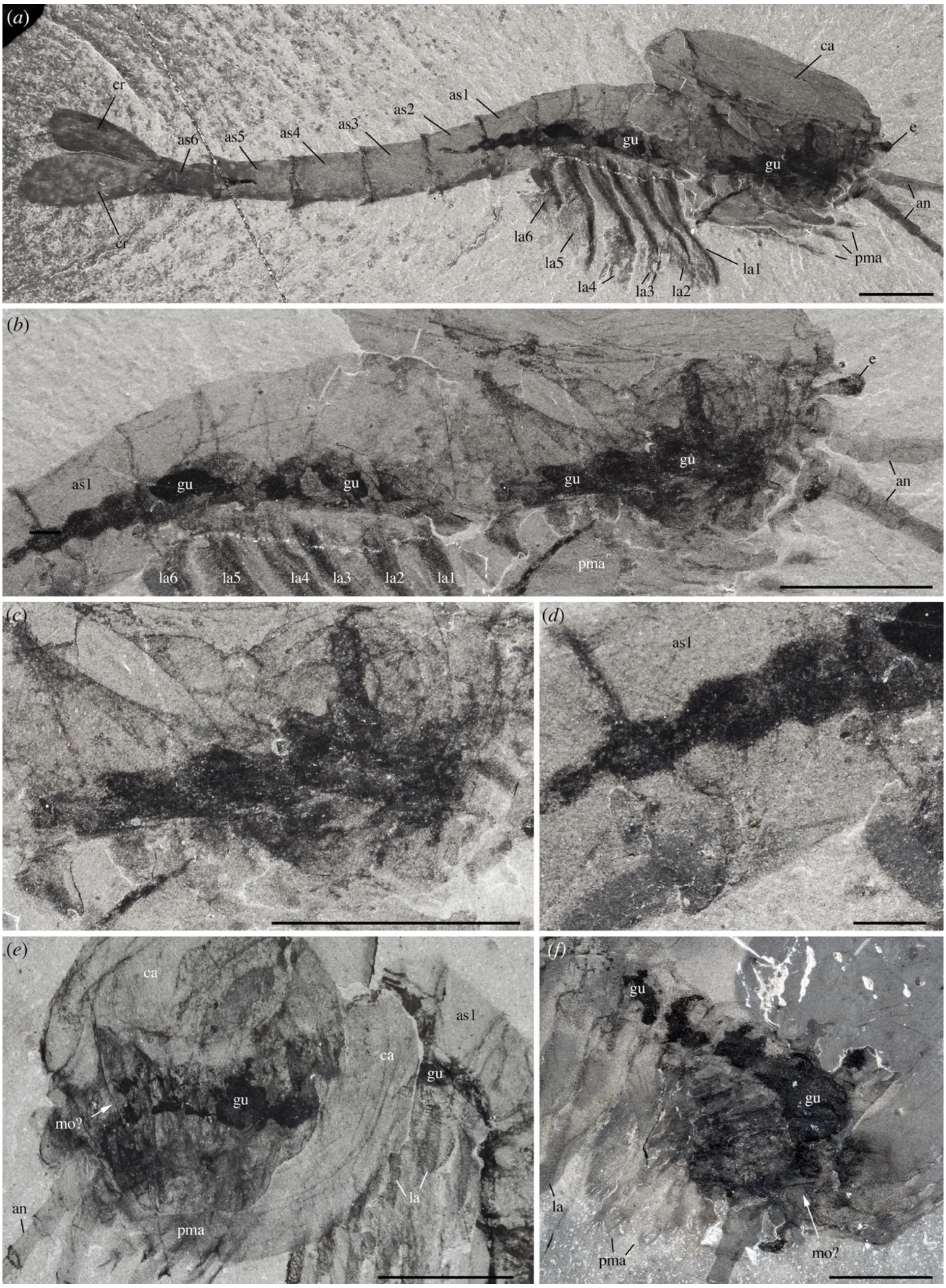
| Coll. N° | Field N° | Fig. | as1 | as2 | as 3 | as4 | as5 | preservation |
|---|---|---|---|---|---|---|---|---|
| ROMIP 56421 | 940677 | 1c; 14c, d; S3 | 0.83 | 1.00 | 1.16 | 1.56 | 1.86 | LATERAL straight |
| ROMIP 56432 | 931318 | 8a-k, 9h, 11h, 12f; 14a,b | 0.83 | 0.94 | 1.04 | 1.27 | 1.78 | LATERAL slightly curved |
| ROMIP 64287 | 910635 | 4p, S18a-d | 0.83 | 0.96 | 1.1 | 1.27 | 1.74 | LATERAL straight |
| ROMIP 64289 | 940874 | 6i | 0.93 | 1.23 | 1.32 | 1.59 | 1.87 | LATERAL straight |
| ROMIP 64281 | 941470 | 1e, 6g, 18i; S12b,d,e, S17e | 0.89 | 1.10 | 1.10 | 1.16 | 1.54 | LATERAL slightly curved |
| USNM 57682 | | 6h, 18g, S5c, S17f | 0.89 | 0.91 | 1.12 | 1.28 | 1.65 | LATERAL slightly curved |
| USNM 83948a | | unfigured | 0.92 | 1.13 | 1.31 | 1.57 | 1.88 | LATERAL slightly curved |
| USNM 114259 | | S17a-d | 0.97 | 1.11 | 1.23 | 1.60 | 1.84 | LATERAL straight |
| USNM 139214 | | 1b, 12h, 14h, 15d; S12a, c | 0.94 | 1.03 | 1.14 | 1.35 | 1.83 | LATERAL slightly curved |
| USNM 268146 | | unfigured | 0.87 | 1.00 | 1.10 | 1.36 | 1.72 | LATERAL straight |
| USNM 529131 | | 1f | 0.85 | 0.95 | 1.09 | 1.25 | 1.56 | LATERAL slightly curved |
| USNM 529138 | | unfigured | 0.89 | 1.12 | 1.25 | 1.43 | 2.00 | LATERAL straight |
| | | | **0.88** | **1.04** | **1.16** | **1.39** | **1.77** | |
| ROMIP 64282 | 930646 | 1g; 26d, e | 0.79 | 1.03 | 1.30 | 1.40 | 1.95 | VENTRAL (?) straight |
| ROMIP 64285 | 941339 | 3e, 10a-d | 0.78 | 0.97 | 1.00 | 1.22 | 1.65 | VENTRAL straight |
| ROMIP 64293 | 940305 | 14e; 24a, b | 1.05 | 1.15 | 1.14 | 1.42 | 1.74 | DORSAL straight |
| ROMIP 64295 | 950242 | 2a-o; 15a, b; 18a | 1.04 | 1.26 | 1.35 | 1.55 | 1.97 | VENTRAL straight |
| **USNM 57681a (L)** | | **19c, S5a,b** | **1.06** | **1.33** | **1.33** | **1.69** | **2.04** | **VENTRAL straight** |
| USNM 83948k | | 18f | 1.00 | 1.17 | 1.11 | 1.35 | 1.77 | VENTRAL straight |
| | | | **0.95** | **1.15** | **1.2** | **1.49** | **1.85** | |
| **JUVENILES** | | | | | | | | |
| USNM 165229 | | 19b | 0.83 | 0.83 | 0.90 | 1.05 | 1.30 | DORSAL straight |
| USNM 268338 | | 19a | 0.78 | 0.84 | 0.92 | 1.09 | 1.33 | LATERAL slightly curved |

maximum value
minimum value
mean value

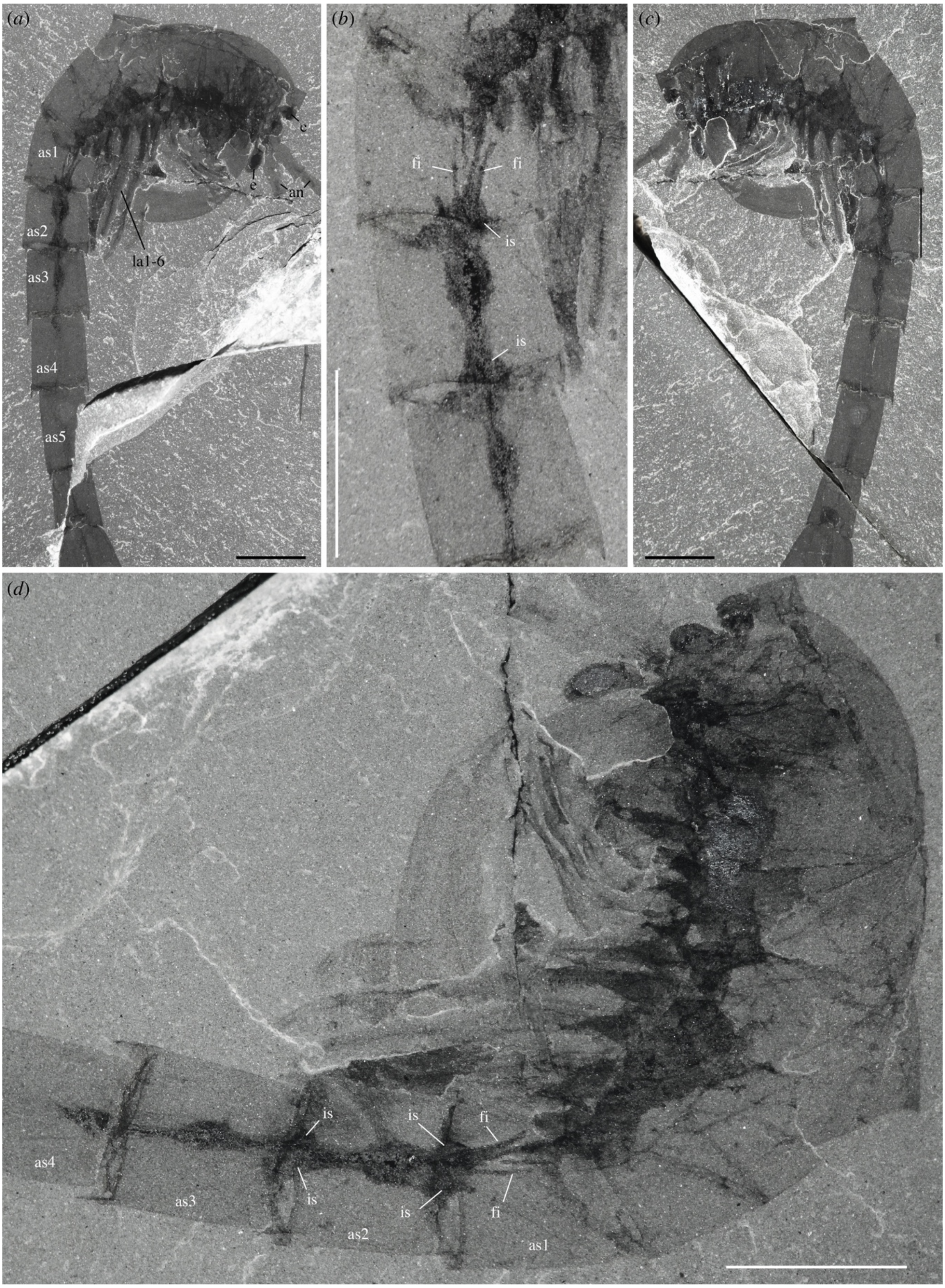
**L= Lectotype**



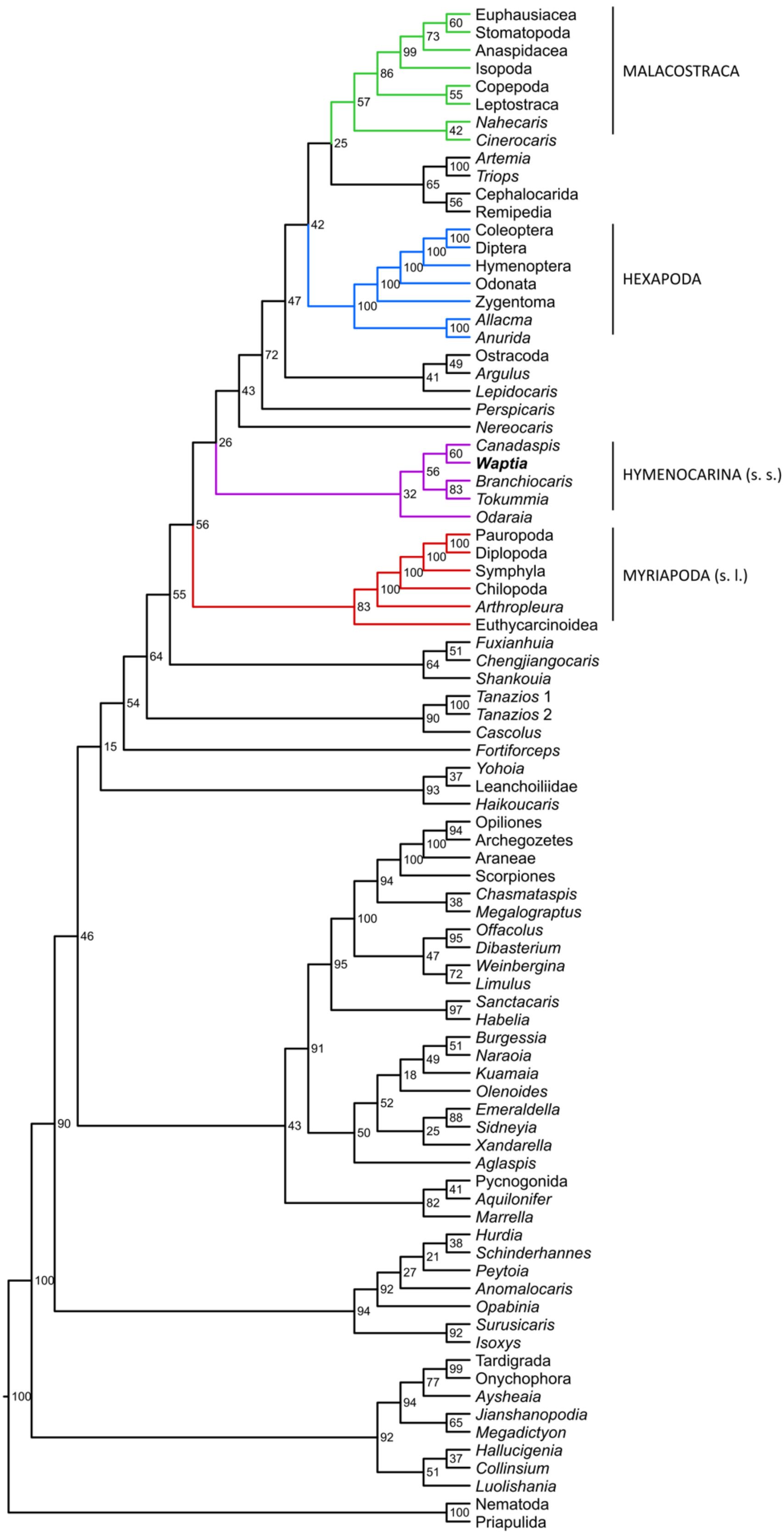

**Electronic supplementary material S16.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; measurements of the abdominal segments. Table and graph showing the variation of the length to width ratio (L/W) in the 1st to 5th abdominal segments. Abbreviations are as follows: as1-5, 1st to 5th abdominal segment; L, Length of abdominal segment; S, Supplementary figure; W, Width of abdominal segment.




**Electronic supplementary material S17**. *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; digestive system. (*a-d*). USNM 114259, general view and details showing anterior and middle part of the gut. All images are light photographs taken under cross-polarized light. (*e*) ROMIP 64281, anteriormost part of the gut; (*f*) USNM 57682, anteriormost part of the gut (overall view see Electronic supplementary material S5c**)**. Abbreviations are as follows: an, antennule; as1-6, 1st to 6th abdominal segments; ca, carapace; cr, caudal ramus; e, eye; gu, gut; la1-6, 1st to 6th pair of lamellate post-cephalothoracic appendages; pma, post-maxillular cephalothoracic appendage. Scale bars: 5 mm in *a-c, e, f*; 1 mm in *d*.




**Electronic supplementary material S18.** *Waptia fieldensis* Walcott, 1912 from the middle Cambrian (Series 3, Stage 5) Burgess Shale, British Columbia, Canada; digestive system, ROMIP 64287, part and counterpart. (*a, c*) General views. (b, d) Details showing intestinal swellings and filament-like structures. All images are light photographs taken under cross-polarized light. Abbreviations are as follows: as1-5, 1st to 5th abdominal segments; fi, ramifying filaments; is, intestinal swelling; la1-6, 1st to 6th pair of lamellate post-cephalothoracic appendages. Scale bars: 5 mm.




**Electronic supplementary material S19.** Maximum clade credibility trees of time-calibrated Bayesian analyses of panarthropod relationships (Mkv+Γ model, 219 characters). Consensus topology resulting from a dataset of 85 adult taxa. Numbers on the right of nodes are posterior probabilities.

**Electronic supplementary material S20.** List of characters used in the present cladistic analysis.

# CHARACTER LIST

The following list is taken from Aria and Caron (2017a) and includes the changes made for the present study as well as those from Aria and Caron (2017b). Character headings refer to the original publication by [ACX], where X is the corresponding number for that character in Aria and Caron (2017). Remarks are not carried over here if no change was made. Characters either new since Aria and Caron (2017), or which have gone through substantial change in overall coding or definition are marked with an asterisk. Some other small corrections were applied to the original matrix but are not reported here in detail.

# GENERAL CHARACTERS

[1] Limbs [AC1]
   0. Absent
   1. Present

[2] External cuticular segmentation [AC2]
   0. Absent
   1. Present

[3] Type of segmentation [AC3]
   0. Sclerotized
   1. Arthrodized (=tergal)

[4] Calcified cuticle [AC4]
   0. Absent
   1. Present

[5] Main calcification type [AC5]
   0. Calcium carbonate
   1. Calcium phosphate

[6] Holometaboly [AC6]
   0. Absent
   1. Present

# LOBOPODIAN CHARACTERS

[7] External anteriorization restricted to a single pair of frontalmost appendages [AC7]
   0. Absent
   1. Present

[8] Lobopodous limbs [AC8]
   0. Absent
   1. Present

[9] Type of main lobopodous trunk limb [AC9]
   0. Short, conical, subequal or shorter than trunk width
   1. Elongated, slender, longer than trunk width

[10] Flap-like lateral limbs [AC10]
   0. Absent

1. Present

[11] Nodes/tubercles/dermal papillae [AC11]
0. Absent
1. Present

[12] Differentiation at limb insertion [AC12]
0. Absent
1. Present

[13] Dorso-lateral sclerites above limb insertion [AC13]
0. Absent
1. Present

[14] Median spine above limb insertions [AC14]
0. Absent
1. Present

[15] Lobopod tip (main trunk limb) [AC15]
0. Double claw
1. Juxtaposed series of claws
2. Pad

[16] Posterior-most single claws [AC16]
0. Absent
1. Present

[17] Posterior claws pointing anteriad [AC17]
0. Absent
1. Present

## VISUAL ORGANS

[18] Ocelli as primary ocular units [AC18]
0. Absent
1. Present

[19] Median eyes [AC19]
0. Absent
1. Present

[20] Number of median eyes [AC20]
0. 2
1. 3
2. 4

[21] Rhabdomeric lateral eye [AC21]
0. Absent
1. Present

[22] Type of lateral eyes [AC22]
0. Simple lens with cup-shaped retina
1. Faceted (compound)
2. Stemmata

[23] Type of corneagenous cells [AC23]

0. Many
1. Two

[24] Tetraconate condition [AC24]
0. Absent
1. Present

[25] Number of nested optic neuropils [AC25]
0. 1
1. 2
2. 3

[26] Multi-layered rhabdomeres [AC26]
0. Absent
1. Present

[27] Eyes embedded within tergal shield [AC27]
0. Absent
1. Present

[28] Opthalmic ridges [AC28]
0. Absent
1. Present

[29] Lateral eyes pedunculate [AC29]
0. Absent
1. Present

[30] Pedunculate eyes large and ovate, part of a prominent ocular segment projecting anteriad [AC30]
0. Absent
1. Present

## HEAD AND CEPHALIC CHARACTERS

[31] Somital head (as tagma I) defined by series of appendages and/or external segmentation [AC31]
0. Absent (only anteriormost defines head)
1. Present

[32] Somites defining anteriormost tagma* [AC31]
0. 5
1. 6
2. 7
3. 8

Remark: Habeliidans and relevant synziphosurines are coded for seven-segmented heads following Aria and Caron (in press).

[33] Tergite of the ocular (protocerebral) somite [AC127]
0. Absent
1. Present

[34] Tergite of the ocular (protocerebral) somite, type [AC128]
0. Rounded
1. Sub-triangular

[35] Tergal sclerotization of the post-ocular somite [AC33]

0. Absent
1. Present

[36] Tergal sclerotization type [AC34]
0. Tergites with posterior expansion, some cephalic tergites can be freely articulating (carapace)
1. Tergites with limited expansion, cephalic tergites fused (shield)

[37] Carapacal valves [AC35]
0. Bivalved
1. Fused

[38] Bivalved carapace type*
0. Type I: Sub-straight cross-section, covering body similar to head shield
1. Type II: Convex cross-section, enveloping body laterally

[39] Type II bivalved configuration [AC36]*
0. Unfused along most of dorsal margin
1. Fused along most of dorsal margin

Remark: Among hymenocarines, we consider that *Odaraia* and *Waptia* present an extensive fusion of the valves with effacement of the median fold.

[40] Covering of the type II bivalved carapace (when body fully extended antero-posteriorly) [AC37]
0. At least two thirds of body length
1. Cephalothorax

[41] Articulation of posterior margin of shield with first trunk segment [AC39]
0. Tergal overlap
1. Closure

[42] Segmental impression in shield [AC40]
0. Absent
1. Present

[43] Occipital lobe [AC41]
0. Absent
1. Present

[44] Pair of occipital carinae [AC42]
0. Absent
1. Present

[45] Anterior reduction of segments and/or appendages [AC43]
0. Absent
1. Present

[46] Compaction of the cephalic unit [AC44]
0. Absent
1. Present

[47] Doublure [AC45]
0. Absent
1. Present

[48] Cephalic kinesis [AC46]
0. Absent

1. Present

## BRAIN CHARACTERS

[49] Ganglia of post-oral appendages fused into single nerve mass [AC47]
0. Absent
1. Present

[50] Contiguity of the first two post-protocerebral ganglia [AC48]
0. Absent
1. Present

[51] Fan-shaped body in brain [AC49]
0. Absent
1. Present

[52] Position of midline neuropil [AC50]
0. Superficial to protocerebrum
1. Embedded within protocerebral matrix

[53] Olfactory lobes linked to a lateral component of protocerebrum by olfactory globular tract [AC51]
0. Absent
1. Present

[54] Deutocerebral olfactory lobe with glomeruli [AC52]
0. Absent
1. Present

[55] Lateral eyes pedunculated [AC53]
0. Absent
1. Present

## STERNITES (CEPHALON)

[56] Sternites [AC54]
0. Absent
1. Present

[57] Endosternum [AC55]
0. Absent
1. Present

[58] Labrum*
0. Absent
1. Present

Remark: Characters describing the hypostome-labrum complex have been reorganized and expanded compared to Aria and Caron (2017). Here, we code the labrum as a common feature shared by all euarthropods, which arguably originates from the protocerebral somite (Scholtz and Edgecombe 2006). Classically, in mandibulates, the "labrum" covers the mouth and such pre-oral structure generally takes two forms: the typical fleshy protrusion of oligostracans, anostracans and other crustaceans, and the sclerotic plates encountered in myriapods, malacostracans and hexapods—which are commonly designed as either "epistome-labrum" or "clypeo-labrum" depending on the group of interest. Pre-labral sclerites in mandibulates are often distinct from the labrum per se and are usually closely associated with the insertion of the antennules. For this reason, the pre-labral sclerite is sometimes referred to as the "hypostome," a common term from the pre-oral sclerite used among extinct euarthropods, especially trilobites and their allies. Such a terminology has been used for instance for Cephalocarida (Olesen *et al.* 2011) but arguably applies to all other crustaceans, including copepods (Schram 1986), leptostracans (Olesen and Walossek 2000) and stomatopods (Haug *et al.* 2012). Herein (chars. 62-64), we therefore harmonize the terms “epistome,” “clypeus” and “hypostome” under the same concept of “hypostome.”

[59] Labrum expression and location*

0. Expressed anteriormost or not distinct
1. Expressed as ventral pre-oral structure

Remark: This character fundamentally distinguishes the anteriormost chelicerate “epistome-labrum” from ventral structures characteristic of Mandibulata. Hymenocarines are considered to belong to the first group.

[60] Type of ventral labrum* [AC58]

0. Single fleshy protrusion
1. Plate with underlying soft tissues

[61] Fusion of pre-oral structures*

0. Absent
1. Present

[62] Hypostome [AC56]*

0. Absent
1. Present

Remark: The hypostome is here defined on the basis of the artiopodan hypostome, that is, as a pre-oral sclerotic structure associated with the insertion of the anteriormost appendages.

[63] Hypostome type [AC57]*

0. Conterminant
1. Natant

[64] Hypostome accommodating antennules and extensively covering the mouth [AC59]

0. Absent
1. Present

Remark: This is a character mostly discriminating the typical artiopodan hypostome.

[65] Labium [AC60]

0. Absent
1. Present

[66] Post-hypostomal sternites externally developed within segments 2–4 [AC61]

0. Absent
1. Present

[67] Fusion of post-hypostomal sternites externally developed within segments 2–4 [AC62]

0. Absent
1. Present

[68] Metastoma [AC63]*

0. Absent
1. Present

Remark: The metastoma is the modified sternite of the first opisthosomal segment in euchelicerates—typically, eurypterids (Dunlop 1997). We also code this character for scorpions (sternum) and harvestmen (aculi genitales) (Dunlop and Lamsdell 2016).

[69] Coxosternite [AC64]
0. Absent
1. Present

[70] Both larval and imaginal head has tendention to form a hypostomal bridge [AC65]
0. Absent
1. Present

## FRONTALMOST APPENDAGES

[71] Arthrodization of first axial appendage [AC66]
0. Absent
1. Present

[72] Ocular (=peduncular) lobes [AC67]
0. Absent
1. Present

[73] Bipartite frontalmost ventral protrusion [AC68]*
0. Absent
1. Present

Remark: This character directly relates to chars. 59-60 insofar as the frontalmost bipartite features observed in hymenocarines are homologized here with the labral lobes of chelicerates. We also code the state present for a number of "Orsten" larvae, given that the "median eyes" identified in these fossils and their subtriangular median sockets are virtually indistinguishable from the anteriormost bipartite lobes seen in protocaridids (Aria and Caron 2017).

[74] Branching frontalmost appendage [AC69]
0. Absent
1. Present

[75] Rami of branching frontalmost appendage originating from different podomeres [AC70]
0. Absent
1. Present

[76] Frontalmost appendage with flagellate extensions [AC71]
0. Absent
1. Present

[77] Frontalmost appendage a chelicera, i.e. chelate or subchelate with only two opposing faces [AC72]
0. Absent
1. Present

[78] Orientation of first axial appendage [AC73]
0. Ventro-frontal
1. Dorsal

[79] Segmentation of frontalmost arthrodized appendage [AC74]
0. Multi-segmented
1. Reduced

[80] Arthrodized frontalmost appendage, multi-segmented type [AC75]
0. Robust, thick branch
1. Long antennular

[81] Inner (ventral) spinose outgrowths on arthrodized frontalmost appendage [AC76]
0. Absent
1. Present

[82] Type of inner (ventral) spinose outgrowths on frontalmost appendage [AC77]
0. Sub-equal length or tapering gradually along entire margin
1. Elongate mid-margin

[83] Secondary spines on inner (ventral) spinose outgrowths of frontalmost appendage [AC78]
0. Absent
1. Present

[84] Outer (dorsal) spinose outgrowths on arthrodized frontalmost appendage [AC79]
0. Absent
1. Present

[85] Outer (dorsal) spinose outgrowth on arthrodized frontalmost appendage with elongate terminal spine [AC80]
0. Absent
1. Present

## OTHER CEPHALIC LIMBS

[86] All cephalic endopods posterior to second pair well-developed [AC81]
0. Absent
1. Present

[87] Endopod of second appendage pair [AC82]
0. Developed
1. Reduced

[88] Endopod of third appendage pair [AC83]
0. Developed
1. Reduced

[89] Endopod of fourth appendage pair [AC84]
0. Developed
1. Reduced

[90] Exopod of fourth appendage pair [AC112]*
0. Developed
1. Reduced

[91] Endopod of fifth appendage pair [AC85]
0. Developed
1. Reduced

[92] Some cephalic endopods are walking limbs [AC86]
0. Absent
1. Present

[93] Repeated appendage morphology in tagma I [AC87]
0. Absent

1. Present

[94] Dichotomy in appendage morphology between tagma I and tagma II [AC88]
0. Absent
1. Present

[95] Proximo-distal differentiation of endopod podomeres in head (tagma I) [AC89]
0. Absent
1. Present

[96] Podomere number in head (tagma I) [AC90]
0. 7
1. <7
2. >7

[97] Post-antennular appendage expressed [AC91]
0. Absent
1. Present

[98] Post-antennular appendage differentiated [AC92]
0. Absent
1. Present

[99] Chelate or sub-chelate termination of post-antennular appendage [AC93]*
0. Absent
1. Present

[100] Ramification of post-antennular appendage [AC95]
0. Uniramous
1. Biramous

[101] Developed endites on endopod of post-antennular appendage [AC96]
0. Absent
1. Present

[102] Endopod of post-antennular appendage annulate or flagellate [AC97]
0. Absent
1. Present

[103] Podomere number of endopod of post-antennular appendage [AC98]
0. <7
1. 7

[104] Coxa on post-antennular appendage [AC99]
0. Absent
1. Present

[105] Exopod of post-antennular appendage, type [AC100]
0. Stenopodous
1. Annulate
2. Rod-shaped
3. Paddle
4. Tripartie

[106] Exopods on cephalic appendages excluding two anteriormost pairs [AC101]
0. Absent

1. Present

[107] Exopod of cephalic appendages excluding two anteriormost pairs, type [AC102]
0. Stenopodous
1. Annulate
2. Rodiform
3. Paddle
4. Tripartite

[108] Multisetose, rounded tip on cephalic exopods [AC103]
0. Absent
1. Present

[109] Partial detachment of exopods from main limb branch in head tagma*
0. Absent
1. Present

Remark: This character expresses the peculiar condition of habeliidans, *Offacolus* and *Dibasterium*, in which the cephalic exopods preserve as partially dissociated from their main biramous branch (Aria and Caron 2017). The exact attachment remains unknown.

[110] Enditic outgrowths on cephalic endopods excluding two anteriormost pairs [AC104]
0. Absent
1. Present

[111] Endopod of third cephalic appendage chelate or subchelate [AC105]
0. Absent
1. Present

[112] Third cephalic appendage with a well-developed gnathobase [AC106]
0. Absent
1. Present

[113] Third cephalic appendage a mandible [AC107]
0. Absent
1. Present

[114] Mandible with three-segmented endopod, appressed on the ventral side of the head, curving inward [AC94]*
0. Absent
1. Present

Remark: This characterizes the endopod of the fuxianhuiid mandible.

[115] Mandibular palp [AC107]
0. Non-developed
1. Developed

[116] Telognathic mandible [AC108]
0. Absent
1. Present

[117] Mandibular gnathal edge [AC109]
0. Consisting of molar and incisor process
1. Only ellipsoid pars molaris present
2. Row of parallel teeth

3. Shovel with terminal teeth
4. Group of paired teeth and hair pad

[118] Mandibular lamellate combs [AC110]
0. Absent
1. Present

[119] Hypopharynx [AC111]
0. Absent
1. Present

[120] Modified endopod/palp on fourth cephalic appendage [AC113]
0. Absent
1. Present

Remark: This character implies the modification of the appendage basis as a mouthpart and the reduction of the endopod of the fourth appendage pair (char. 89), whereby the complete reduction of the endopod is coded "0".

[121] Modified endopod/palp on fourth cephalic appendage, type [AC114]*
0. Reduced, vestigial, undeveloped
1. Well developed

[122] Post-mandibular plate formed by the fusion of the maxilla and the intermaxillary sternum [AC115]
0. Absent
1. Present

[123] Cephalic appendages 4 and 5 ending with chelate termination [AC116]
0. Absent
1. Present

[124] Fifth cephalic appendage [AC117]
0. Integrated to gnathal plate (labium)
1. Reduced, enditic

[125] Fifth cephalic appendage vestigial [AC118]
0. Absent
1. Present

[126] Fifth cephalic appendage with developed palp [AC119]
0. Absent
1. Present

Remark: Same requirements for coding as for char. 120, but with respect to fifth cephalic pair.

[127] Internalization of mouthparts [AC120]
0. Absent
1. Present

[128] Oral cone [AC121]
0. Absent
1. Present

[129] Atrium oris [AC122]
0. Absent
1. Present

## MOUTH AND STOMODAEAL AREA

[130] Mouth opening anteriorly (as opposed to ventrally or dorso-ventrally) [AC123]
0. Absent
1. Present

[131] Type of circumoral structures [AC124]
0. Toothed lips
1. Lamellae
2. Plates
3. Hypostome-labrum complex

[132] Circumoral structures sclerotized [AC125]
0. Absent
1. Present

[133] Proboscis [AC126]
0. Absent
1. Present

## ALIMENTARY TRACT AND OTHER INTERNAL CHARACTERS

[134] Stomach [AC129]
0. Absent
1. Present

[135] Stomach in a frontal position [AC131]
0. Absent
1. Present

[136] Stomach—additional pouch [AC132]
0. Absent
1. Present

[137] Secondary organs connected to the central digestive duct [AC132]
0. Absent
1. Present

[138] Secondary digestive organs serially repeated along the post-cephalic portion of the gut [AC133]
0. Absent
1. Present

[139] Shape of post-cephalic secondary digestive structures [AC134]
0. Reniform
1. Bulgy triangles
2. Caeca

[140] Striations on post-cephalic secondary digestive structures [AC135]
0. Absent
1. Present

[141] Branching of post-cephalic secondary digestive structures [AC136]
0. Absent
1. Present

[142] Differentiation of cephalic secondary digestive structures (compared to trunk) [AC137]
0. Absent
1. Present

[143] Ramification of cephalic secondary digestive structures [AC138]
0. Absent
1. Present

[144] Branching of cephalic secondary digestive structures [AC139]
0. Absent
1. Present

[145] Peritrophic membrane [AC140]
0. Absent
1. Present

[146] Metameric ganglia on nerve cord [AC141]
0. Absent
1. Present

[147] Metanephridia with sacculus containing podocytes [AC142]
0. Absent
1. Present

[148] Segmental invaginations of neuroectoderm giving rise to ventral organs [AC143]
0. Absent
1. Present

## TRUNK

[149] Thorax [AC144]
0. Absent
1. Present

[150] Number of thoracic somites [AC145]
0. 11
1. 5
2. 8
3. 3

[151] Abdomen [AC146]
0. Absent
1. Present

[152] Number of core trunk segments [AC147]
0. >14
1. 12-14
2. 9
3. 7-8
4. <7

[153] Seventh appendage integrated into the prosoma [AC148]*
0. Absent
1. Present

Remark: This character only applies to Chelicerata and their stem groups (see also char. 32).

[154] Tergite of eighth somite (counting the ocular somite as the first) drastically reduced as a "microtergite"*
0. Absent
1. Present

Remark: See Dunlop and Lamsdell (2016) for a review of this character across chelicerates.

[155] Post-cephalic appendages covered by sclerotic plates (opercula)*
0. Absent
1. Present

Remark: Arguably the strongest apomorphy of Euchelicerata (Dunlop and Lamsdell 2016; Aria and Caron in press).

[156] Multisegmentation [AC149]
0. Absent
1. Present

[157] Tergo-sternal decoupling [AC150]
0. Absent
1. Present

[158] Tergo-sternal decoupling, type [AC151]
0. Polypody
1. Polypody and "polysternity"
2. "Polytergity" (autapomorphy of symphylan myriapods)

[159] Pleurae [AC152]
0. Reduced or fused
1. Developed

[160] Tergo-pleural rings [AC153]*
0. Absent
1. Present

[161] Pleural orientation [AC154]
0. Horizontal
1. Around body

[162] Pleural length [AC155]
0. Short, i.e. equal or inferior to body diameter
1. Long, i.e. exceeding body diameter

[163] Articulating ridge [AC156]
0. Absent
1. Present

[164] Articulating ridge, type [AC150]
0. Single
1. Antero-posterior

[165] Transverse stipital muscle [AC150]
0. Absent
1. Present

## TRUNK APPENDAGES AND GENERAL APPENDICULAR CHARACTERS

[166] Proximo-distal differentiation of endopod podomeres in tagma II [AC159]
0. Absent
1. Present

[167] Podomere number in tagma II [AC160]
0. 7
1. <7
2. >7

[168] Maxillipeds [AC161]
0. Absent
1. Present

[169] Tergites of maxilliped segments fused to head shield [AC162]
0. Absent
1. Present

[170] Single main maxilliped [AC163]
0. Absent
1. Present

[171] Slit sensilla [AC164]
0. Absent
1. Present

[172] Basis (basipod) [AC165]
0. Absent
1. Present

[173] Basipod formed of at least two elements [AC166]
0. Absent
1. Present

[174] Basipod multi-segmented [AC167]
0. Absent
1. Present

[175] Multiple endites on basipod [AC168]
0. Absent
1. Present

[176] Proximal endite [AC169]
0. Absent
1. Present

[177] Coxa as entire pre-basal podomere [AC170]
0. Absent
1. Present

[178] Precoxa as whole pre-coxal podomere [AC171]
0. Absent
1. Present

[179] Pleurites formed by several sclerotic elements surrounding limb insertion [AC172]

0. Absent
1. Present

[180] Arrangement of pleurites [AC173]
0. Outer/proximal and distal/inner sets
1. Multiple sclerotic pieces

[181] Gnathobases [AC174]
0. Absent
1. Present

[182] One or more gnathobase(s) reduced in tagma I [AC175]
0. Absent
1. Present

[183] Secondary appendicular outgrowths on trunk [AC176]
0. Absent
1. Present

[184] Secondary appendicular outgrowths on trunk, type [AC177]
0. Lobopodous
1. Sclerotized

[185] Proximal lamellae [AC178]
0. Absent
1. Present

[186] Proximal lamellae internalized [AC179]
0. Absent
1. Present

[187] Trunk endopod reduced posterior to head tagma [AC180]
0. Absent
1. Present

[188] Limb arthrodization in trunk [AC181]
0. Absent
1. Present

[189] Trunk exopod posterior to head tagma, type [AC182]*
0. Paddle/lobe
1. Rodiform
2. Annulate
3. Reduced
4. Three-segmented
5. Phyllopodous

[190] Endopod strongly developed in thorax (or anterior trunk if thorax undifferentiated) [AC183]
0. Absent
1. Present

[191] Phyllopodous-type limbs anywhere on body [AC184]
0. Absent
1. Present

[192] Terminal endopods stenopodous [AC185]

0. Absent
1. Present

[193] Identical morphology of endopod and exopod rami on pleopods/post-thorax [AC186]
0. Absent
1. Present

[194] Annulation of at least one pair of exopods [AC187]
0. Absent
1. Present

[195] Subdivision of at least one pair of exopods [AC188]*
0. Absent
1. Present

[196] Subdivision of at least one pair of exopods, type [AC188]*
0. Bipartite
1. Tripartite

[197] Attachment segment in lobate exopod [AC189]
0. Absent
1. Present

[198] Epipod [AC191]
0. Absent
1. Present

[199] Endite as a latero-distal projection on endopod podomeres [AC192]
0. Absent
1. Present

[200] Pusher legs with paddle tips [AC193]
0. Absent
1. Present

[201] Developed endites on endopod podomeres in trunk (tagma II and III) [AC194]
0. Absent
1. Present

[202] Paired spines on endopod podomere [AC195]
0. Absent
1. Present

[203] Short spines on endopod podomere [AC196]
0. Absent
1. Present

[204] Multiple setae on endopod podomere [AC197]
0. Absent
1. Present

[205] Paired elongate spines distally on endopod [AC198]
0. Absent
1. Present

[206] Limb tip [AC199]

0. Pad
1. Juxtaposed claws
2. Trident of claws
3. Chelate or sub-chelate
4. Double claw
5. Multiple spines
6. Single claw

## POSTERIOR TERMINATION

[207] Sclerotization of termination [AC200]
0. Absent
1. Present

[208] Telson developed [AC201]
0. Absent
1. Present

[209] Telson type [AC202]
0. Spine
1. Plate
2. Spatula

[210] Anus location [AC203]
0. Terminal, last segment
1. Base of telson

[211] Caudal rami [AC204]
0. Absent
1. Present

[212] Additional caudal processes [AC205]
0. Absent
1. Present

[213] Furca [AC206]
0. Absent
1. Present

[214] Uropods sensu stricto [AC207]
0. Absent
1. Present

[215] Caudal rami, type [AC208]
0. Spinose
1. Rounded
2. Filamentous
3. Annulate

[216] Pygidium [AC209]
0. Absent
1. Present

[217] Type of pygidial fusion [AC210]
0. Partial
1. Complete

[218] Axial elevation of pygidium [AC211]
0. Absent
1. Present

[219] Pygidial ornamentation [AC212]
0. Smooth
1. Spinose

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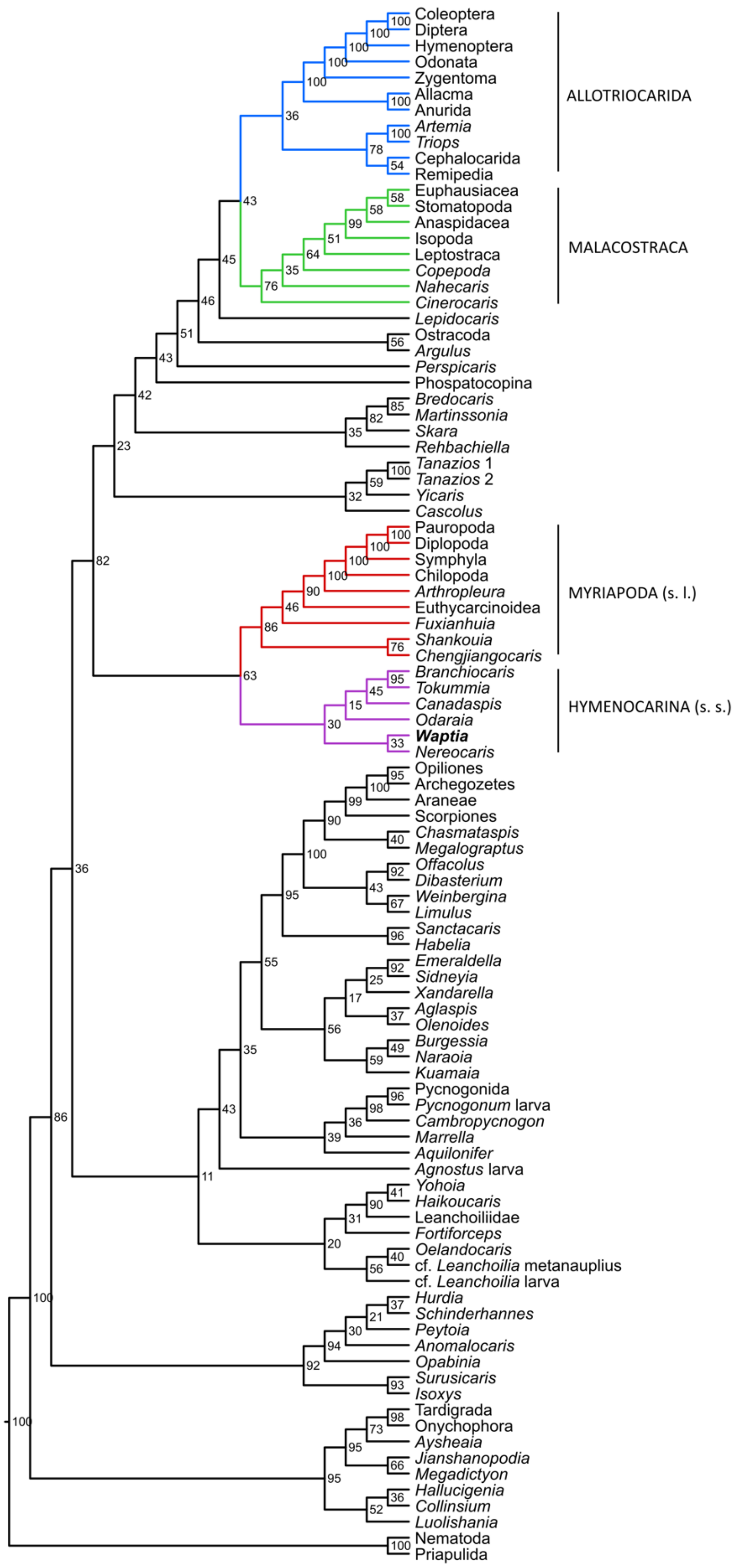


**Electronic supplementary material S22.** Maximum clade credibility trees of time-calibrated Bayesian analyses of panarthropod relationships (Mkv+Γ model, 219 characters). Consensus topology resulting from a dataset of 97 larval and adult taxa. Numbers on the right of nodes are posterior probabilities.