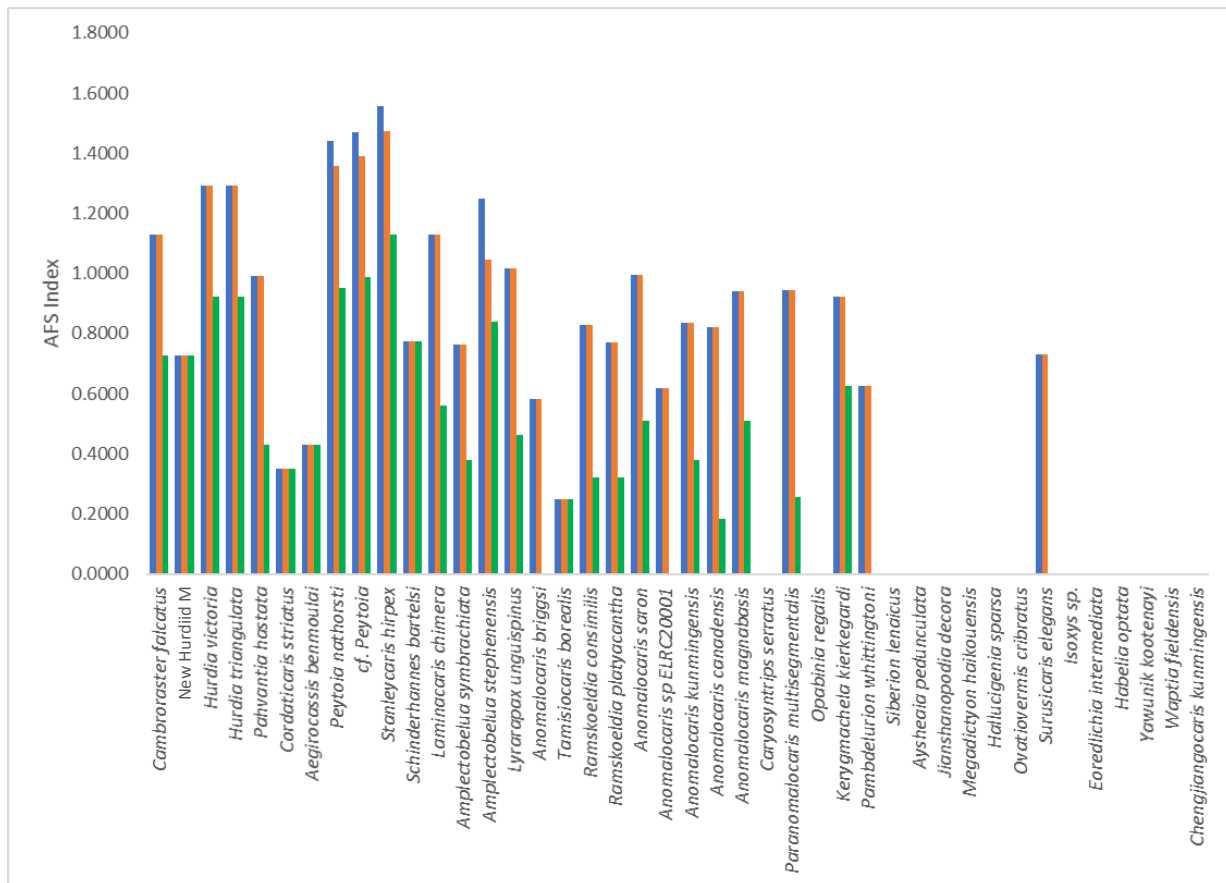


Methods: Coding morphological discontinuity in AFS

As mentioned in the main text, delimitation of outgrowths into sets for calculation of AFS was based on the identification of discontinuous variation in shape or size in adjacent outgrowths. For example, the hypertrophied endite relative to more distal endites in *Amplectobelua* (Cong et al. 2017) represents a strong discontinuity in size, but gradual shifts like the decrease in endite size distally and subtle size alternation in *Anomalocaris* (Daley and Edgecombe 2014) were not considered to qualify. Likewise, the proximalmost endite in *Stanleycaris*, which cants distally relative to more distal endites constitutes a strong discontinuity in shape, but gradual changes like the reduction of auxiliary spines on the distal endites of *Anomalocaris* were not considered to qualify.

In our primary coding strategy (1), outer spines were considered independently from endites/gnathites and were counted as separate groupings even in cases where they look similar – for example, the outer spines and distal gnathites on the *Stanleycaris* appendage – as their differing positions likely imply differing functions. As an alternative strategy (2), we coded these similar gnathites (i.e. those lacking auxiliary spines and morphologically similar to the outer spines) as part of the same grouping as the outer spines. Finally, we also tested the impact of omitting outer spines entirely from the calculation (3). Tip values for the three strategies can be seen in Supplementary Figure 1.



Supplementary Figure 1: Alternative AFS coding schemes. Blue = coding scheme (1) used in Figure 8, Orange = coding scheme (2), Green = coding scheme (3).

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List of possible synapomorphies

Radiodonta (questionably including <i>Caryosyntrips</i>)	24 – tripartite carapace complex 39 – thirteen podomeres in distal appendage region 51 – auxiliary spines
Hurdiidae	15 – posteriorly displaced eyes (except in <i>Schinderhannes</i>) 44 – mesially curved endites (except in <i>Schinderhannes</i>) 49 – elongate endites on 5-7 podomeres 58 – auxiliary spines perpendicular to endite axis (convergent with <i>Laminacaris</i> ?)
Hurdiids with large carapaces (smallest clade containing <i>Aegirocassis</i>)	29 – pointed H-element (reversed in some taxa) 40 – reduced distal podomeres in frontal appendage 62 – highly reduced outer spines on frontal appendage 71 – eight or nine main trunk flaps
Amplectobeluidae+Anomalocarididae	11 – neck separating head and trunk 21 – nodular circumoral plate ornament (convergent with <i>Cordaticaris</i>) 46 – alternation of endite lengths
Amplectobeluidae sensu stricto	45 – one or more endites projecting at an acute angle to the distal end of the appendage
Tamisiocarididae	54 – three or more posterior auxiliary spines

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Phylogenetic Character List

This list is based on that originally published in (Moysiuk and Caron 2019) with additional modifications made in (Caron and Moysiuk 2021). Additional edits are detailed below for each character.

New Taxa

'Anomalocaris' kunmingensis (Wang, Huang, and Hu 2013) – we accept here the hypothesis of (Zeng et al. 2018) for the identity of the oral cone of this species

Anomalocaris magnabasis (Pates et al. 2019)

Anomalocaris sp. (ELRC 20001) (Chen, Ramsköld, and Zhou 1994) – previously identified as *A. saron* (Hou, Bergström, and Ahlberg 1995), but differing significantly in appendage morphology relative to specimens now attributed to this species (Cong et al. 2018)

cf. *Peytoia* (Daley and Budd 2010)

Paranomalocaris multisegmentalis (Wang, Huang, and Hu 2013)

Ramskoeldia platyacantha (Cong et al. 2018)

New Hurdiid M (Caron and Moysiuk 2021)

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General characters

- [1] External subdivision of integument, type
 - 0. Annulated
 - 1. Segmented
- [2] Arthrodization of body (tergal sclerites joined by arthrodial membranes)
 - 0. Absent
 - 1. Present
- [3] Externally developed pleurae
 - 0. Absent
 - 1. Present
- [4] Digestive tract with metameric paired diverticulae
 - 0. Absent
 - 1. Present
- [5] Appendicular outgrowths from the body, number per somite
 - 0. Single
 - 1. Paired
- [6] Biramous limbs with conjoined endopod and exopod
 - 0. Absent
 - 1. Present
- [7] One or more pairs of appendages bearing cuticular outgrowths serially arranged along their length
 - 0. Absent
 - 1. Present
- [8] Arthrodization of one or more pairs of appendages
 - 0. Absent
 - 1. Present

Head characters

- [9] Head tagma, defined by the fusion of several anterior tergites and/or differentiation of several pairs of limbs forming a cohesive anteriormost functional unit
 - 0. Absent
 - 1. Present
- [10] Tergal sclerotization in head tagma, type
 - 0. Tergites fused together with limited posterior expansion (shield)
 - 1. Cephalic tergites with high degree of posterior expansion, overlapping more posterior segments (carapace)
- [11] Frontalmost head separated from trunk by narrow ‘neck’ region

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- 0. Absent
- 1. Present

Remarks: Recoded *Opabinia* (0 to 1).

- [12] Compound lateral eyes
- 0. Absent
 - 1. Present
- [13] Compound lateral eyes, type
- 0. Sessile
 - 1. Stalked
- [14] Compound lateral eyes, number
- 0. Two
 - 1. Four or more
- [15] Lateral compound eyes, position
- 0. Anterior of head, immediately adjacent to the mouth and frontalmost appendages
 - 1. Far posterior to mouth and frontalmost appendages
- [16] Mouth, position
- 0. Anterior
 - 1. Ventral
 - 2. Posterior facing, gut recurved
- [17] Hypostome
- 0. Absent
 - 1. Present
- [18] Ring of circumoral sclerites
- 0. Absent
 - 1. Present
- Remarks:* We were previously conservative about our coding of characters relating to the mouth in *Lyrarapax* (Moysiuk and Caron 2019), however upon reviewing the evidence we agree with (Liu et al. 2018) that sclerotic circumoral plates are likely present. We have recoded this taxon accordingly. We also recoded *Megadictyon* (? to 1) to acknowledge the probable sclerotization of its oral armature.
- [19] Differentiation of at least two types of sclerites in circumoral ring (i.e. ‘oral cone’)
- 0. Absent
 - 1. Present
- [20] Circumoral structures, organization
- 0. Triradial
 - 1. Tetraradial

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- [21] Circumoral plates, ornamentation
0. Smooth
1. Rounded or triangular nodes and furrows
- [22] Inner pharyngeal toothed plates
0. Absent
1. Present

Remarks: Somewhat recoded to better represent similarities between radiodont and large lobopodian mouth structures.
- [23] Dorsal ocular sclerite (i.e. anterior sclerite, H-element)
0. Absent
1. Present
- [24] Head carapace complex consisting of a dorsal (H-element) and paired lateral or ventrolateral (P-element) sclerites
0. Absent
1. Present

Remarks: Recoded *R. consimilis* (? to 1)
- [25] Head carapace complex, size
0. Small, confined to anteriormost area near the frontal appendage attachment site, giving the head a trapezoidal shape
1. Large, covering close to half or more of the body length, including several lamellar bands or flaps
- [26] Head carapace complex, reticulate ornamentation
0. Absent
1. Present
- [27] Head carapace complex, tuberculate ornamentation
0. Absent
1. Present
- [28] H-element, length relative to width
0. Length greater than width
1. Length equal to or shorter than width
- [29] H-element, anterior extends into point or spine
0. Absent
1. Present
- [30] H-element, posterolateral notches
0. Absent
1. Present

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- [31] H-element, axial area posterior margin
0. Essentially flush with posterior margin of lateral areas
 1. Extended into a projection
- [32] H-element, posterior margin of lateral areas extended into elongate wing-like posterolateral processes
0. Absent
 1. Present
- [33] H-element, marginal spines
0. Absent
 1. Present
- [34] P-element, posterior end
0. Broad and rounded
 1. Tapering to a narrow or pointed end
- [35] P-element, posterior notch
0. Absent
 1. Present

Frontal Appendages

- [36] Strong differentiation of frontalmost pair of appendages from more posterior pairs
0. Absent
 1. Present
- [37] Bases of frontalmost appendages occupying the entire “head,” leaving no interspace with trunk appendages
0. Absent
 1. Present
- Remarks: recoded Aysheaia (- to 0).*
- [38] Strong proximodistal differentiation of podomeres and/or cuticular outgrowths along appendage
0. Absent
 1. Present
- Remarks: Recoded Pambdelurion and Kerygmachela (0 to 1).*
- [39] Podomeres in distal articulated portion of arthrodized frontal appendage (including distal tip, but not the peduncle), number
0. 11 or fewer
 1. 12
 2. 13
 3. 14 or more

Remarks: Updated character with new states to more precisely differentiate taxa.

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- [40] Highly reduced distalmost podomeres
0. Absent
1. Present
- [41] Outward kink separating proximalmost (peduncle, or shaft) and distal portions of the appendage
0. Absent
1. Present
Remarks: Recoded as inapplicable for hurdiids apparently lacking a peduncle.
- [42] Pair of spiniform cuticular outgrowths per podomere
0. Absent
1. Present
Remarks: Recoded *R. consimilis* (? to 1).
- [43] Pair of spiniform cuticular outgrowths per podomere, type
0. Both outgrowths similar and located on the inside of appendage (second endite)
1. Outgrowths morphologically differentiated, one located on the inside (endite) and one on the medial side of appendage (gnathite)
Remarks: Recoded *C. serratus* (0 to 1), *A. stephenensis* (0 to 0&1), *R. consimilis* (? to 0).
- [44] Endites, curvature
0. Straight
1. Curving mesially around the mouth, forming a basket
- [45] Endites, attachment angle
0. All endites projecting straight from the supporting podomere
1. One or more endites projecting forward at an acute angle to the distal end of the appendage
Remarks: Modified character state definitions and coding to accommodate variation in orientation of hurdiid proximalmost endites.
- [46] Adjacent endites, alternation in relative length
0. Absent
1. Present
- [47] One or more endites elongate (at least 1.5 times the height of the supporting podomere)
0. Absent
1. Present
- [48] Elongate endites, number per podomere
0. Single
1. Paired

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- [49] Elongate endites, location
0. Hypertrophied endite(s) on one or two proximal podomeres opposing the appendage tip to form a claw
 1. Elongate endites on 5-7 proximal podomeres
- [50] Endites on distal podomeres
0. Highly reduced or absent on some podomeres
 1. Present on all podomeres
- Remarks:* Highly modified from previous character definition and coding.
- [51] One or more appendicular outgrowths (endite or medial spinous outgrowth) bearing auxiliary spines
0. Absent
 1. Present
- [52] Auxiliary spines, serial occurrence
0. Present on only one endite
 1. Present on multiple endites
- [53] Posterior auxiliary spines on at least one endite or gnathite
0. Absent
 1. Present
- Remarks:* Slightly changed character definition and coding to also account for the posterior auxiliary spine on the gnathites of *S. hirpex*.
- [54] Posterior auxiliary spines, maximum number per endite or gnathite
0. One
 1. Two
 2. Three or more
- Remarks:* Recoded *S. hirpex* (- to 0).
- [55] Auxiliary spines on some gnathites
0. Absent
 1. Present
- Remarks:* [New Character] Auxiliary spines are uniquely present on the gnathites of *Stanleycaris* and *cf. Peytoia*. Applicable only with reference to Ch. 53.
- [56] Anterior auxiliary spines, maximum number per endite
0. 1
 1. 2-5
 2. 6-10
 3. 11 or more
- Remarks:* Recoded *S. hirpex* (? to 2).
- [57] Auxiliary spines on endites, arrangement of multiple spines
0. Radiating from base of endite

Supplementary text – Moysiuk & Caron 2021

1. Pectinate (arranged in parallel along the endite)

- [58] Auxiliary spines on endites, angle
0. Directed distally, at an acute angle to the tip of the endite
 1. Directed roughly perpendicular to the endite long axis

- [59] Alternation of long and short auxiliary spines on pectinate endite
0. Absent
 1. Present

- [60] Auxiliary spines, curvature
0. Straight
 1. Gently curving
 2. Strongly hooked

Remarks: Added state 1 to differentiate the typical hurdiid condition from the very strongly hooked spines present in *Hurdia* and *Cambroraster*.

- [61] Outer spines
0. Absent
 1. Present

Remarks: Redefined character slightly and changed coding; subsequent character now accommodates more fine differentiation.

- [62] Distalmost outer spines, type
0. Stubby and highly reduced
 1. Elongate, weakly curving, and finely tapering
 2. Strongly recurved (talon-like) and robust

Remarks: State 0 added.

- [63] Serrated outer margin of the appendage
0. Absent
 1. Present

Remarks: [New Character] Codes for the presence of small spines (multiple per podomere) along the outer edge of the appendage, independent from the typical larger singular dorsal spines. Found in *Paranomalocaris* and *Caryosyntrips*.

Trunk characters

- [64] Sternites
0. Absent
 1. Present

- [65] Arthrodization of post-frontal appendages
0. Absent
 1. Present

- [66] Post-frontal appendages bearing serially arranged cuticular outgrowths

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- 0. Absent
 - 1. Present
- [67] Gnathobases
- 0. Absent
 - 1. Present
- [68] Lobopodous appendages, shape
- 0. Equal to or shorter than body diameter, conical
 - 1. Elongate, significantly longer than body width, cylindrical
- [69] Trunk appendages are lateral flaps
- 0. Absent
 - 1. Present
- [70] Reduced anterior flaps or bands of lamellae
- 0. Absent
 - 1. Present
- [71] Main trunk flaps, number
- 0. 8-9
 - 1. 10-12
 - 2. 13 or more
- [72] Relative width of trunk at anterior and posterior segments
- 0. Body less than three times as wide at the anterior as at the posterior
 - 1. Body at least three times as wide at the anterior as at the posterior
- [73] Flap rays
- 0. Absent
 - 1. Present
- [74] Lamellae
- 0. Absent
 - 1. Present
- [75] Lamellae, position
- 0. Arranged in bands crossing the body and appendages
 - 1. On appendages only
- [76] Differentiated posterior blades
- 0. Absent
 - 1. Present
- [77] Tail fan, type
- 0. Single pair of lobes

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1. Several pairs of lobes
- [78] Caudal furcae
0. Absent
 1. Present
- [79] Telson
0. Absent
 1. Present

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