# List of characters

The following morphological characters were chosen in the continuity of phylogenetic studies on stem arthropods (e.g. Briggs and Fortey 1989; Wills *et al.* 1997; Budd 2002; Cotton and Braddy 2004) and adapted to latest descriptions and views. Recent datasets that have been consulted in particular include Edgecombe *et al.* (2011), Stein and Selden (2012) and Ortega-Hernández *et al.* (2013).

# I. Cephalon

I.1. Type of cephalic carapace

0. Small sclerite or composed of separate plates

1. Two longitudinal valves

2. Single shield

I.2. Shape of anteriormost margin of cephalic shield

0. Convex

1. Straight or sub-straight

2. Sub-triangular, rostral

I.3. Detached frontal sclerite

0. Absent

1. Present

Some stem arthropod taxa, such as fuxianhuiids (Hou and Bergström 1997; Yang *et al.* 2013) and several bivalved forms (Briggs 1978; Legg and Caron 2014), possess a frontal sclerite usually called the “anterior sclerite” and distinct from the cephalic shield/carapace proper.

I.4. Hypostome

0. Absent

1. Present

The hypostome is here defined as a pre-oral sclerotized plate but is homologized with the softer “labrum” of crustaceans in cases where the latter is a single pre-oral bulge (see, e.g., *Cephalocarida* for a separate condition (Addis *et al.* 2007)).

I.5. Head configuration

1. Two-somital
2. Five-somital (eyes + four appendage pairs)
3. Six-somital (eyes + five appendage pairs)
4. Seven-somital (eyes + six appendage pairs)
5. Eight-somital (eyes + seven appendage pairs)

The head of fuxianhuiids has been described as three-somital (Hou and Bergström 1997; Yang*, et al.* 2013) with the cephalic shield overlapping the reduced anterior tergites of the trunk. Rather than forcing the autapomorphy for *Fuxianhuia* in our dataset, we preferred to openly code this state as “uncertain” in order to test for the most parsimonious placement with respect to more common configurations.

I.6. Condition of cephalic shield posteriorly overlapping trunk tergites

0. Absent

1. Present

Although the conditions may be plesiomorphically related, this character is considered inapplicable for bivalved carapaces.

I.7. Condition of eyes notched dorsally into head shield

0. Absent

1. Present

I.8. Secondary median eyes

0. Absent

1. Present

This character does not take into account the position of the median eyes (ventral or dorsal).

**II. Frontalmost appendage**

II.1. Polysegmented condition (8 segments or more)

0. Absent

1. Present

II.2. Elongate condition

0. Absent

1. Present

This condition applies to the main ramus of the appendage, and thus leanchoiliids are coded 0.

II.3. Paired inner spines

0. Absent

1. Present

II.4. Developed spines on the distal outer margin

1. 0. Absent
2. 1. Present

II.5. Number of inner rami

1. 4
2. 3
3. 2

Applicable when the appendage is differentiated into a chelate complex, excluding here the condition of *Hurdia*.

II.6. Distalmost segment with rounded edge

0. Absent

1. Present

Coded 1 in all antennulas.

II.7. Flagellate condition of the multi-chelate appendage

0. Absent

1. Present

II.8. Median podomeres forming a swollen peduncle

0. Absent

1. Present

II.9. Peduncular multi-chelate appendage with enlarged base and elongate rami

0. Absent

1. Present

The “great appendages” of certain leanchoiliids are conspicuously larger (*Yawunik*, *Leanchoilia superlata*) than others (*Alalcomenaeus*, *Actaeus*, *L. persephone* (García-Bellido and Collins 2007)) due mostly to a more prominent base and stouter, more elongate rami. The condition is unclear in *L. illecebrosa,* which possibly represents an intermediate condition. Specimens of *L. illecebrosa* seem to exhibit both conditions (Hou and Bergström 1997; Hou *et al.* 2004; Liu *et al.* 2007), calling into question the homogeneity of the morphotype. Ideally, a morphometric analysis including additional leanchoiliid morphospecies (e.g. *L. protagonia*) would help clarify the significance of this character.

II.10. Claw complex distally on the distalmost ramus

0. Absent

1. Present

# III. Post-frontal cephalic appendages

III.1. Post-oral cephalic appendages

0. Lopobodous or weakly sclerotized

1. Arthrodized

III.2. One or more reduced cephalic endopod(s)

0. Absent

1. Present

III.3. Exopod-bearing cephalic appendages

0. Absent

1. Present

III.4. Sub-segmentation of cephalic exopod

0. Absent

1. Present

**IV. Trunk**

IV.1. Shape of tergo-sclerites

1. Contiguous ring-shaped
2. Tergites laterally extended into pleurae

IV.2. Fine serration of pleural margins

1. Absent
2. Present

IV.3. Parallel dorsal carinae

1. Absent
2. Present

IV.4. Number of trunk segments

0. 20+

1. 14-16

2. 13

3. 12

4. 11

5. 10-

IV.5. Abdomen (=whole appendage-free section of the trunk)

0. Absent

1. Present

IV.6. Post-abdomen (=one or two appendage-free segments before tailpiece)

0. Absent

1. Present

Several stem taxa clearly have one or two segments at the posterior end of the trunk that are devoid of appendages, a characteristic generally recognized in their description (e.g. (e.g. Haug *et al.* 2012b; Stein and Selden 2012) but sometimes confounded with longer abdomens in character matrices. We treat the two conditions as separate.

IV.7. Decoupling of trunk tergites and appendages

0. Absent

1. Present

Fuxianhuiids and *Xandarella* have been reported to have trunk segments housing more than one pair of appendages (Hou and Bergström 1997).

# V. Trunk appendages

V.1. Basipod

0. Absent

1. Present

V.2. Proximal endite

0. Absent

1. Present

V.3. Reduction of trunk endopods

0. Absent

1. Present

This character is coded independently from the presence of an abdomen.

V.4. Elongate articulated podomeres

0. Absent

1. Present

This character relates to the transition from short (wider than long) limb segment into disto-proximally square- or longer rectangular-shaped podomeres, likely articulated via arthrodial membranes. Non-arthrodized limbs are here considered inapplicable.

V.5. Differentiated podomeres

0. Absent

1. Present

This character reflects the differentiation of certain podomeres within a limb, characteristically by the elongation of some of them in accordance with the improvement of locomotion style.

V.6. Club-like projections on podomeres

0. Absent

1. Present

Tentatively coded in both *Agnostus* (Müller and Walossek 1987) and *Kunmingella* (Shu *et al.* 1999), although these features may not originate from the same margins.

V.7. Type of outgrowths on the inner margin of podomeres

1. No outgrowth
2. Distal margins of podomeres drawn out in pairs of spines
3. Bulging medial outgrowths with tufts of short setose projections (“endites”)

V.8. Podomere number

0. 8+

1. 7

The number of podomeres on the standard trunk appendage is particularly conserved amongst euarthropods. Diverging counts in the literature often come from the choice of whether to include or exclude the distal claw; it is included here. Variations in some crown taxa, usually considered to be subdivisions of the original segments, are interpreted here as secondarily derived.

V.9. Exopod attached or abutting the first exopodial podomere

0. Absent

1. Present

This character has been stressed by Stein (2008) to be a possible anatomical link between *Oelandocaris* and *Agnostus*. It is, in fact, present in a range of stem taxa including *Leanchoilia* (Haug *et al.* 2012a), *Emeraldella* (Stein and Selden 2012) and trilobitomorphs (Ramskold and Edgecombe 1996).

V.10. Division of the trunk exopod

0. Absent

1. Present

For a review of this character and the following exopod characters, see notably Ramsköld and Edgecombe (1996), Cotton and Braddy (2004) and Ortega-Hernández *et al*. (2013). Excluding the epipodites of crustaceans, the division is usually bipartite, but exceptions exist in, e.g., *Emeraldella* and *Kuamaia* (Stein and Selden 2012; Ortega-Hernandez*, et al.* 2013) that are not coded here.

V.11. General shape of exopod

0. Lobate

1. Rod-like and more or less curved

This is a character mostly grouping Xandarellida and Nektaspida (Ortega-Hernandez*, et al.* 2013). The condition in trilobites seems to vary, as the exopod is somewhat lobate in, e.g. *Olenoides* and *Eoredlichia* (Whittington 1975; Ramskold and Edgecombe 1996; Zhang *et al.* 2007) but thin and rod-like in *Triarthrus* (Harrington 1959). We decided to code 1 in *Olenoides* to reflect the existence of this condition in Trilobita.

V.12. Spinules on exopodial margins

0. Absent

1. Present

V.13. Lamellae on exopodial margins

0. Absent

1. Presence

This character is separate from the previous one in order to accommodate the presence of both states in *Emeraldella* (Stein and Selden 2012).

V.14. Imbrication of lamellae

0. Absent

1. Present

This distinction has been stressed notably by Ortega-Hernández *et al*. (2013) to discriminate the condition in chelicerates and trilobitomorphs from that of, e.g., leanchoiliids.

# VI. Tailpiece

VI.1. Tailpiece type

0. Soft

1. Sclerotized

According the observations by Legg and Vannier (2013), it is coded 0 in *Isoxys*.

VI.2. Telson

0. Absent

1. Present

VI.3. Pygidium

0. Absent

1. Present

The pygidium is a fusion of the posterior trunk tergites.

VI.4. Shape of telson

0. Lanceolate

1. Spatulate

2. Spinose

3. Furcate

VI.5. Ornamentation of telson

0. Absent

1. Present

VI.6. Length (type) of telson adornments

0. Short (teeth)

1. Long (spines)

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