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Supporting Online Material for

A Probable Pollination Mode Before Angiosperms: Eurasian, Long-Proboscid Scorpionflies

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Materials and Methods

The supplemental data provided herein accompany the Ren et al. article, cited above. First, we identify the examined specimens examined and present mouthpart measurements and structural features discussed in the text. We provide stratigraphic and geochronologic context of the Eurasian deposits containing the fossils. For the cladistic analyses, we include tables indicating our approach, provide a list of characters and character-states used, the character-state matrix, and figure the six best supported trees. In the following section, we provide the details of a study involving examination of all specimens for pollen. Next, we provide data and results of the elemental analyses of the *Jeholopsyche liaoningensis* specimen, mentioning details of the instrumentation and methodology that we employed. Then, we provide a summary of the reproductive features of five major groups of seed plants that likely were targeted by long-proboscid scorpionflies during the mid Mesozoic. Last, we describe and diagnose two new genera and five species in three families that we discuss in the text and illustrate in Figures 1 and 2. We also emend the description of a previously known taxon, *Vitimopsyche*.

Specimen Data

Table S1: Specimens Examined

	Specimen number	Family	Genus and species	Sex	Authors
1.	CNU-M-LB2005001	Aneuretopsychidae	*Jeholopsyche* sp.	?	Ren, Shih & Labandeira 2009
2.	CNU-M-LB2005002-1&2	Aneuretopsychidae	*Jeholopsyche liaoningensis* gen. et sp. nov.	♂	Ren, Shih & Labandeira 2009
3.	CNU-M-NN2005001-1&2	Pseudopolycentropodidae	*Pseudopolycentropus janeannae* sp. nov.	♀	Ren, Shih & Labandeira 2009
4.	CNU-M-NN2005003	Pseudopolycentropodidae	*Pseudopolycentropus janeannae* sp. nov.	♀	Ren, Shih & Labandeira 2009
5.	CNU-M-NN2005004-1&2	Pseudopolycentropodidae	*Pseudopolycentropus janeannae* sp. nov.	♂	Ren, Shih & Labandeira 2009
6	CNU-M-NN2005030-1&2	Pseudopolycentropodidae	*Pseudopolycentropus janeannae* sp. nov.	♀	Ren, Shih & Labandeira 2009
7	CNU-M-NN2005031-1&2	Pseudopolycentropodidae	*Pseudopolycentropus janeannae* sp. nov.	?	Ren, Shih & Labandeira 2009
8.	CNU-M-NN2005002	Pseudopolycentropodidae	*Pseudopolycentropus novokshonovi* sp. nov.	♀	Ren, Shih & Labandeira 2009
9.	CNU-M-NN2005020-1&2	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	♀	Ren, Labandeira & Shih 2009
10.	CNU-M-NN2005021-1&2	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	♂	Ren, Labandeira & Shih 2009
11.	CNU-M-NN2005024	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	?	Ren, Labandeira & Shih 2009
12.	CNU-M-NN2005025-1&2	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	♀	Ren, Labandeira & Shih 2009
13.	CNU-M-NN2005027-1&2	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	?	Ren, Labandeira & Shih 2009
14.	CNU-M-NN2005029	Mesopsychidae	*Lichnomesopsyche gloriae* gen. et sp. nov.	?	Ren, Labandeira & Shih 2009
15.	CNU-M-NN2005022-1&2	Mesopsychidae	*Lichnomesopsyche daohugouensis* gen et sp nov	?	Ren, Labandeira & Shih 2009
16.	CNU-M-HP2005001-1&2	Mesopsychidae	*Vitimopsyche kozlovi* sp. nov.	?	Ren, Labandeira & Shih 2009
17.	AMNH BU1444	Pseudopolycentropodidae	*Parapolycentropus burmiticus* Grimaldi & Rasnitsyn 2005	♀	(*S1*)
18.	PIN 2066/1290	Pseudopolycentropodidae	*Pseudopolycentropus latipennis* Martynov 1927	♀	(*S2*)
19.	PIN 2554/1324	Aneuretopsychidae	*Aneuretopsyche minima* Rasnitsyn & Kozlov 1990	?	(*S3*)
20.	PIN 2904/1198	Aneuretopsychidae	*Aneuretopsyche rostrata* Rasnitsyn & Kozlov 1990	♀	(*S3*)
21.	PIN 1668/1958	Aneuretopsychidae	*Aneuretopsyche vitimensis* Rasnitsyn & Kozlov 1990	?	(*S3*)

Table S2: Mouthpart and related data on mid-Mesozoic long-proboscid scorpionflies

Family, figures, sources	*Species and examined specimens*	*Localities and age*	*Siphonal Features*					*Clypeal area* (mm^2)	*Antennal type*	*Sex*
			Length (mm)	*Width* (mm)	*Food tube dia.* (mm)	*Surface*	*Terminus*			
Mesopsychidae										
(Fig. 1A–N)	*Lichnomesopsyche gloriae* Ren, Labandeira & Shih 2009, gen. et sp. nov. [CNU-M-NN2005020, -021, -024, -025, -027, and -029]	Daohougou, Inner Mongolia, China; Middle Jurassic (Bathonian–Callovian boundary)	9.9 8.9 8.9 10.1 >8.9 9.0 —	0.24 0.28 0.18 0.25 0.24 0.30 0.47	0.111 0.130 0.060 0.138 0.137 0.132 0.186	Coarse setae	Pseudo-labellum (Type 1)	0.387 (n = 7)	Filiform –broad	♀,♂
(Fig. S3)	*Lichnomesopsyche daohugouensis* Ren, Labandeira & Shih, 2009, gen. et sp. nov. [CNU-M-NN2005022]	Daohougou, Inner Mongolia, China; Middle Jurassic (Bathonian–Callo vian boundary)	8.8 —	0.34 0.31	0.094 0.115	Coarse setae	Pseudo-labellum (Type 1)	0.361	Filiform –broad	—
(Fig. 1O–R)	*Vitimopsyche kozlovi* Ren, Labandeira & Shih, 2009 sp. nov. [CNU-M-HP2005001]	Pingquam, Hebei China, Early Cretaceous (Barremian)	,9.0	0.58	0.14	Smooth	Absent	0.436	Pectinate	—
Aneuretopsychidae										
(Fig. 2A–E)	*Jeholopsyche liaoningensis* Ren, Shih & Labandeira 2009, gen. et sp. nov. [CNU-M-LB2005002]	Huangbanjigou, Liaoning, China, Early Cretaceous (Barremian)	6.8	0.34	0.10	Smooth, annulated	V–pad, pseudo-labellum (Type 2)	0.493	Filiform–compact	♀
(*S3*)	*Aneuretopsyche minima* Rasnitsyn & Kozlov 1990 [PIN-2554/1324]	Aulie, Shymkent, Kazakhstan; Late Jurassic (Kimmeridgian)	4.7	0.18	0.060?	Finely, transversely ridged	Absent	—	Filiform–compact	?
(*S3*)	*Aneuretopsyche rostrata* Rasnitsyn & Kozlov 1990 [PIN-2904/1198]	Aulie, Shymkent, Kazakhstan; Late Jurassic (Kimmeridgian)	7.3	0.21	0.075?	Finely, transversely ridged	Faint pseudo-labellum (Type 3)	—	Filiform–compact	♀

(Fig. 2G–I)	*Jeholopsyche* Ren, Shih & Labandeira 2009, sp. indet. [CNU-M-LB2005001]	Huangbanjigou, Liaoning, China, Early Cretaceous (Barremian)	5.8	0.275	0.085	Trans-versely ridged	Pseudo-labellum (Type 3)	—	—	Filiform–compact	?
Pseudopolycentropodidae											
(Fig. 2M–O) (*S1*)	*Parapolycentropus burmiticus* Grimaldi & Rasnitsyn 2005 [AMNH Bu-1444]	Tanai, Kachin, Myanmar; Early Cretaceous (Albian)	1.33	0.121	0.014	Setate, annu-lated	Lobate (Type 4)	—	—	Monili-form	♀
(Fig 2J–L)	*Pseudopolycentropus janeannae* sp. nov. Ren, Shih & Labandeira 2009, [CNU-M-NN2005001, -003, -004, -030 & -031]	Daohugou, Inner Mongolia, China; Middle Jurassic (Bathonian–Callo-vian boundary)	1.63 1.63	0.130 0.125	0.038 0.038	Fine setae	Absent	—		Filiform compact	♀,♂
(*S2*)	*Pseudopolycentropus latipennis* Martynov 1927 PIN-2066/1290]	Aulie, Shymkent, Kazakhstan; Late Jurassic (Kimme-ridgian)	>1.8	0.085	??	Fine setae	Tip broken	—		Filiform compact	♀
(Fig. S4)	*Pseudopolycentropus novokshonovi* sp. nov. Ren, Shin & Labandeira 2009 [CNU-M-NN2005002]	Daohugou, Inner Mongolia, China; Middle Jurassic (Bathonian–Callo-vian boundary)	1.5	0.13	0.038	Trans-versely ridged?	Tip broken	0.468		Filiform–compact	?

Deposits, Ages and Preservation

Age dates for the four deposits are secure at the geologic-stage level of resolution, and are based on isotopic dates (*S4*,*S5*), biostratigraphic correlation with marine or other zonations (*S6*,*S7*), and palynology (*S1*,*S8*). Myanmar amber is least resolved, and has been attributed to a mid Cretaceous age ranging from late Albian to Turonian (*S1*), although biostratigraphic evidence centers on the earlier date (*S6*). Preservation of the studied insect bodies range from good to superb, with most informative data on head and mouthpart structure originating from 13 specimens of the Bathonian–Callovian Jiulongshan Formation of Inner Mongolia, China (*S5*,*S7*,*S9*), and three specimens of the Barremian Yixian Formation of western Liaoning and northern Hebei, China (*S4*,*S10*,*S11*). All five deposits preserve anatomy to various extents, expressed as surface projections of inner features or as amber-embedded external structure, particularly proboscis details including fine to coarse setae in distinctive patterns, cuticular ridges and annulations, and terminal pads or fleshy lobes (Figs. 1,2).

Phylogenetic Analyses

We conducted a cladistic analysis using morphological data to understand the relationships of these three lineages of mid Mesozoic scorpionflies to Permian–Recent Mecoptera and to other related panorpoid taxa (*S12*), including Diptera (true flies), Siphonaptera (fleas), Trichoptera (caddisflies) and Lepidoptera (moths and butterflies). Our analysis consisted of 53 morphological characters (Table S4), 19 extinct and 12 extant taxa (Table S5), which were run under six sets of varying options to produce six best trees (Fig. S1); the best-supported cladogram is shown in Fig. 3. The purpose of this exercise was to place the long-proboscate (siphonate) scorpionfly lineages into a proper phylogenetic context within the Antliophora, not an exhaustive reanalysis of the non-neuropteroid Holometabola. The Amphiesmenoptera was coded as a unitary taxon in this analysis, as previous work has indicated a significantly robust sister-group relationship of the Trichoptera + Lepidoptera (*S11*), reflected herein.

Table S3: Comments on the Character-State Matrix

1. The goal of study was to identify the phylogenetic position of presumptive fossil mecopteroids with siphonate mouthparts, namely the Pseudopolycentropodidae, Mesopsychidae and Aneuretopsychidae. We included in the total analysis units that are either undisputedly monophyletic (Amphiesmenoptera) or at least appear to form clades with in respect to the above three families, such as the extant Panorpoidea *sensu stricto* (= Orthophlebiidae (if distinct of Panorpidae) + Panorpidae + Panorpodidae + Choristidae + Apteropanorpidae). Morphologically poorly documented extinct taxa were ignored, such as the Permocentropidae.
2. Outgroups with respect to Mecopteroidea were taken to be those characterizable taxa, which presumably are closely related to that group but not excessively specialized. It has been established that the group venationally closest to the most plesiomorphic mecopteroids (for example, the Kaltanidae and Protomeropidae) is the Neuroptera (= Planipennia) and particularly its least derived family, Permithonidae *sensu lato*, which overwhelmingly includes Permian taxa (*S2*,*S11*). However, the Neuroptera as a whole is a highly diverse and often

consist of venationally variable or deviant taxa. More recent neuropterans belonging to the subclade surviving the end-Permian extinction are highly specialized, primarily because of larval adaptations. It is unknown when these apomorphies were established, and whether the Permithonidae possessed such specializations. For this reason, we have selected only the latter, and not Neuroptera as a whole for an outgroup, along with the Raphidioptera and Megaloptera. Characters that are uncertain for Permithonidae are scored as unknown ("?").

3. As a result, the following unitary groups were considered in our analyses: Raphidioptera; Megaloptera; Neuroptera: Permithonidae *sensu lato* (see above); Amphiesmenoptera; Diptera; Siphonaptera; and, within Mecoptera, the Kaltanidae, Permopanorpidae, Belmontiidae, Liassophilidae, Permotanyderidae, Robinjohniidae, Permotipulidae, Nannochoristidae, Thaumatomeropidae, Boreidae, Sibiriothaumatidae, Permochoristinae, Sylvopanorpinae, Agetopanorpinae, Pseudonannochoristinae (the last four traditionally comprising the family Permochoristidae), Mesopsychidae, Pseudopolycentropodidae, Aneuretopsychidae, Meropeidae, Parachoristidae, Bittacidae, Muchoriidae, Dinopanorpidae, Eomeropidae, and Panorpoidea *sensu stricto* (as defined above). The oldest known mecopterans are from the Carboniferous–Permian boundary of Carrizo Arroyo (New Mexico, USA), which are illustrated by Rasnitsyn (*S13*) but currently not described, and included in the Kaltanidae. *Moravochorista carolina* Kukalová-Peck and Willmann (*S14*), described as the oldest known mecopteran, is excluded from consideration because it does not fit current concept of the order, and the available information does not exclude attribution of this fossil to "hypoperlids" or their equivalent in reassigned taxa.
4. Characters polymorphic within a unitary group are shown in the matrix as ("p").
5. An aim of this analysis is to accommodate extinct taxa into a resulting cladogram. A preference is provided to characters likely to be preserved in the fossil record. Consequently, delicate or otherwise seldom-encountered characters that are typically unavailable in fossils were not explored among the extant taxa. Examples include microscopic, larval, and internal characters. Preferred characters are wing-related, especially venational features that constitute about half (51 %) of all characters in the matrix.
6. Two-state characters with a (putatively) apomorphic state appear only once in the matrix. We did not score unique autapomorphies of unitary groups in the matrix.
7. The results of the analysis are shown in Fig. S1, of which one of the two best-supported cladograms (upper-right of Page 11) was selected for Fig. 3. We collapsed ten overwhelmingly extant mecopteran clades into two subsuming sister-clades, Mecoptera 1 and Mecoptera 2, and combined the three outgroup clades—the Megaloptera (alderflies and dobsonflies), Permithonidae (an extinct taxon) and Raphidioptera (snakeflies)—into a single Neuroptera clade, all of which preserve relevant cladogram topology. Of 19 extinct taxa with sufficient morphological character-state data, most have been characterized as having a "primitive scorpionfly" or similar facies (*S15*,*S16*). We identified more encompassing clades of Mecopteroidea, Antliophora, Amphiesmenoptera and Panorpoidea in Fig. 3.

Table S4: List of Characters and Character-States

1. **Fluid feeding in adults.** The ingesting of liquid food only, if any, without solid macroscopic particles entering digestive tract, termed chylophagy (new term). **0** – absent (neuropteroids); **1** – present (mecopteroids).
2. **Fusion of the labrum. 0** – free (majority of taxa); **1** – fused with clypeus (present in Mecoptera other than Permochoristidae; Mesopsychidae; Pseudopolycentropodidae; variable in Boreidae).
3. **External labral muscles. 0** – present (majority of taxa); **1** – lost (Mecoptera; Siphonaptera).
4. **Mandibular articulation.** Ordered states: **0** – chewing, with both articulations well developed (Megaloptera; Raphidioptera; archaic Amphiesmenoptera such as Protomeropina, Micropterygidae, Agathiphagidae, Heterobathmiidae; **1** – chewing, with anterior articulation weak at best (Mecoptera except Aneuretopsychidae, Mesopsychidae, and Pseudopolycentropodidae; unknown in most extinct families); **2** – piercing (dagger- to stylet-like) or lost (Diptera; Siphonaptera; most Amphiesmenoptera; Mecoptera such as Aneuretopsychidae, Mesopsychidae, Pseudopolycentropodidae).
5. **Siphonate mouthparts**. **0** – absent (majority of taxa); **1** – present.
6. **Disposition of maxillary palp.** Ordered states: **0** – free, segmented (majority of taxa); **1** – short, permanently adpressed to the base of beak (Mecoptera: Mesopsychidae; Pseudopolycentropodidae); **2** – lost as a segmented organ (Aneuretopsychidae).
7. **Subdivision of labial processes. 0** – prementum not deeply cleft, often with apical appendage(s), bearing glossae and/or paraglossae, or ligula (majority of orders); **1** – deeply cleft, only palps borne apically (Mecoptera).
8. **Labial palp segmentation.** Ordered states: **0** – > 2 segments (majority of taxa); **1** – Two-segments (most Mecoptera); **2** –apparently lost, at least < 2 segments (Aneuretopsychidae; Mesopsychidae; Pseudopolycentropodidae); variable (1–25) in Siphonaptera.
9. **Thorax integration. 0** – with prothorax at least slightly movable and not very small and with meso- and metathorax of comparable size and structure (majority of orders, except for "higher" Lepidoptera); **1** – consolidated, with prothorax (often also metathorax) much reduced and immovable (Diptera; Mecoptera: Mesopsychidae; Pseudopolycentropodidae; Aneuretopsychidae).
10. **Pleural muscle attached to Ax1. 0** – absent (neuropteroids); **1** – present (Amphiesmenoptera; Diptera; Mecoptera, contrary to Hörnschemeyer (*S17*); also in Hymenoptera, found by Rasnitsyn (*S18*), possibly indicating that this muscle contributes to the ground plan for the Holometabola). Polarity is not apparent.
11. **Number of wing pairs. 0** –at least one pair present (majority of taxa); **1** – both pairs lost (Boreidae; Apteropanorpidae; Siphonaptera; some Bittacidae; some Amphiesmenoptera; some Diptera).
12. **Forewing/hindwing size.** Unordered states: **0** – homonomous with hindwing not much shorter than forewing (majority of taxa); **1** – heteronomous with hind wing much shorter than forewing, occasionally lost (Mecoptera: Pseudopolycentropodidae; Liassophilidae; Permotanyderidae; Permotipulidae; some Amphiesmenoptera); **2** – heteronomous with hind wing reduced in size and modified into a haltere (Diptera).
13. **Forewing shape. 0** – relatively normal: from long and narrow to wide and rounded; **1** – subtriangular with straight hind margin before well-defined posterior angle (Pseudopolycentropodidae; Liassophilidae; Permotanyderidae; some Lepidoptera).
14. **Forewing width of preradial space. 0** – moderately wide to substantially wide (common in majority of winged orders, particularly in their older representatives); **1** – narrow (Diptera;

Mecoptera: Pseudopolycentropodidae; Aneuretopsychidae; also in advanced forms in most holometabolan orders except those with forewings that are highly modified or lost).

15. **Apical consolidation in the forewing Subcostal Vein (SC). 0** – joining the Costal Vein (C) (Raphidioptera, most Mecoptera and Trichoptera); **1** – joining the Radius Vein (R) (Megaloptera; Neuroptera; basal Trichoptera; Mecoptera, such as some Nannochoristidae). Polarity is not apparent.
16. **Length of SC. 0** – long (well beyond midwing); **1** – short (approximately to midwing or shorter).
17. **Number of preapical forebranches of SC (in addition to the Humeral Vein). 0** – >3 (within Mecoptera such as Kaltanidae; as a secondary polymerization in Thaumatomeropidae, Meropeidae, Eomeropidae, some Panorpoidea *sensu stricto* such as *Taeniochorista*; in some Aneuretopsychidae, as revealed in new data from China); **1** – <4.
18. **Number of forebranches of SC (subdivision of Character 17, State 1). 0** – >2; **1** – <3.
19. **Number of forebranches of SC (subdivision of Character 18, State 1). 0** – >1; **1** – <2.
20. **Branching of the SC (subdivision of Character 19, State 1). 0** – with forebranch(es); **1** – with no forebranch.
21. **Presence of free base of the forewing Media Anterior Vein (MA) before fusion with the Radial Sector Vein (RS). 0** – present (neuropteroids); **1** – lost (mecopteroids).
22. **Linearity of the forewing Radius Vein (R) stem. 0** – straight or evenly bent (majority of orders); **1** – kinked (Diptera; Permotanyderidae; variable in Liassophilidae; Aneuretopsychidae such as *Aneuretopsyche*; Amphiesmenoptera, including various Trichoptera from the Triassic to the Recent).
23. **Number of branches of the RS, excluding the MA. 0** – >2; **1** – <3.
24. **Number of RS branches (subdivision of Character 23, State 1). 0** – >1; **1** – <2.
25. **Basic branching pattern of RS (subdivision of Character 23, State 0)**. **0** – dichotomously branching; **1** – pectinate, with a posterior comb (Parachoristidae; Thaumatomeropidae; Panorpoidea except Choristidae; possibly also in Bittacidae: Plesiobittacinae).
26. **Branching of MA**. **0** – with 2 or more branches; **1** – with 2 branches only.
27. **"Thyridulum" presence**. The thyridulum is a new term for a small desclerotized spot at the branching point of the RS and MA veins. Ordered states: **0** – absent (Neuropteroidea; Diptera; many Amphiesmenoptera; Mecoptera, such as Kaltanidae and Nannochoristidae); **1** – present (most Mecoptera; Amphiesmenoptera such as some Trichoptera, including *Permomerope*); **2** – shifted basad on the RS + MA common vein stem (Pseudonannochoristinae).
28. **Position of the posteriormost MA branch of the forewing with respect to the wing membrane**. **0** – neutral or weakly concave (majority of taxa); **1** – convex (Diptera; Mecoptera: Bittacidae).
29. **Number of Media Posterior Vein (MP) branches. 0** – >6; **1** – <7.
30. **Number of MP branches (subdivision of Character 29, State 1)**. **0** – >4; **1** – <5.
31. **Thyridium presence.** The thyridium is a desclerotized spot at branching of the MP. Ordered states: **0** – absent (Neuropteroidea; Diptera; Siphonaptera); **1** – present (Mecoptera; Amphiesmenoptera); **2** – shifted apicad on MP 1 + 2 common vein (Belmontiidae).
32. **Development of the base of the Media 5 Vein (M_5). 0** – modestly developed (Kaltanidae; Permochoristidae; Liassophilidae; Permotanyderidae; Parachoristidae; and others; possibly also Thaumatomeropidae); **1** – short to nonexistent due to fusion of MP and CuA Veins (Mesopsychidae, except *Lichnomesopsyche*; Pseudonannochoristinae; Robinjohniidae; Nannochoristidae; Bittacidae; some Permochoristinae; Parachoristidae; rare in Kaltanidae).
33. **Length of the sub-basal fusion of MP and CuA Veins. 0** – short to nonexistent (majority of Mecoptera); **1** –long (Robinjohniidae; Nannochoristidae; Bittacidae).

34. **Base of the CuA. 0** – long, oblique, straight or bent to S-shaped; **1** –short and resembling a cross-vein.
35. **CuA at junction with M5**. **0** – angular; **1** – smooth, with M_5 resembling a cross-vein (Panorpoidea *sensu stricto*). Polarity is not apparent.
36. **CuA branching in the forewing**. **0** – branched (majority of orders); **1** – simple (Diptera; Mecoptera other than Kaltanidae).
37. **Hindwing course of the free base of the MA before fusion with the RS**. **0** – long, sinuate (Neuroptera; Raphidioptera; Megaloptera); **1** – short, displaced far basad or usually lost (mecopteroids).
38. **Sub-basal course of the hindwing Cubitus Posterior Vein (CuP) in relation to the first Anal Vein (1A)**. **0** – free (neuropteroids; Mecoptera: Mesopsychidae, Pseudopolycentropodidae, as indicated by secondary loss of fusion implied from rudimentary basal fusion indicated by Novokshonov [1997] in *Mesopsyche* (*S3*) and also in *Vitimopsyche*); **1** – fused for a distance (mecopteroids, except Mesopsychidae and Pseudopolycentropodidae).
39. **Leg pubescence (setae only).** Unordered states: **0** – unspecialized (all orders other than Mecoptera except Nannochoristidae, Boreidae, Eomeropidae, and Permian Permochoristidae); **1** – forming regular encirclements at least locally (Mecoptera, including some Triassic Permochoristidae such as *Liassochorista*, Aneuretopsychidae, Parachoristidae, Orthophlebiidae, and all extant families except Nannochoristidae, Boreidae, and Eomeropidae); **2** – typically chaotic but tibia locally characterized by a distinct encircling pattern (possibly secondarily disorganized (Mesopsychidae, Pseudopolycentropodidae); **3** – lost, with only spines present (Eomeropidae).
40. **Leg modification**. **0** – nonsaltatorial (majority of taxa); **1** –hind legs saltatorial (Siphonaptera; Mecoptera such as Boreidae; some Diptera).
41. **Spination in the adult proventriculus**. **0** – without true acanthae (spinose processes as defined in 1969 by Richards and Richards (*S19*) and Hepburn (*S20*), even if bearing needle-like structures of unknown delicate structure associated with internal ridges or folds on the internal surface of the proventriculus (majority of orders); **1** – with true acanthae covering the smooth, but neither ridged nor folded, internal surface of the proventriculus (Siphonaptera; Mecoptera).
42. **Male tergum and sternum 9**. **0** – free (majority of orders); **1** – fused as a ring (Mecoptera, except minimally in Permopanorpidae; variable in Boreidae and Bittacidae).
43. **Contralateral male gonocoxae**. **0** – free, individually movable (majority of taxa); **1** – fused at least basally, not individually movable except ordinary spreading and approaching closure (Mecoptera other than Permochoristidae).
44. **Presence of the male gonostylus with a stylar organ. 0** – absent (majority of taxa); **1** – present (Mecoptera except secondarily in Choristidae, Panorpodidae, and Panorpidae).
45. **Sperm pump. 0** – absent (majority of orders); **1** – present (Diptera; Mecoptera except Boreidae and Nannochoristidae; unknown in fossils).
46. **Abdominal segment housing the female genital opening**. **0** – 8 (majority of orders; Mecoptera such as Permochoristidae, Mesochoristidae, Aneuretopsychidae, Nannochoristidae); **1** – 9 (other Mecoptera).
47. **Contralateral basal segment of female cerci**. **0** – free (majority of taxa); **1** – connected, with a transverse sclerotization (Mecoptera, except Permopanorpidae, Permochoristidae, Mesopsychidae, Pseudopolycentropodidae, Bittacidae, and basal Boreidae). The cercus apparently was lost in Aneuretopsychidae.
48. **Ovariole type.** Unordered states: **0** – meroistic polytrophic (Neuroptera; Amphiesmenoptera; Diptera; Siphonaptera: Histrichopsylloidea; “true Mecoptera”); **1** – neopanoistic

(Siphonaptera: Pulicoidea; Mecoptera: Boreidae, Nannochoristidae; Megaloptera: Corydalidae); **2** – meroistic telotrophic (Raphidioptera; Megaloptera: Sialidae).

49. **Pupa appendages**. Unordered states: **0** – free (majority of orders), **1** – adherent (Diptera; higher Lepidoptera).
50. **Silken cocoon produced by larval labial glands**. **0** – no (Neuropteroidea, majority of Mecoptera); **1** – yes (Amphiesmenoptera, Siphonaptera, Mecoptera: Boreidae). Polarity is not apparent.
51. **Larval eye. 0** – compound (Mecoptera); **1** – scattered stemmata (majority of taxa) or lost. Polarity is not apparent.
52. **Extensive muscle reduction in the common excretory duct of the labial gland. 0** – no (majority of orders); **1** – yes (Mecoptera, Diptera, Siphonaptera).
53. **Claw type of the larval thoracic legs.** Unordered states: **0** – with paired claws, 6-segmented (Neuropteroidea, except Sisyridae); **1** –with claw-like pretarsus (majority of orders); **2** – lost (Diptera; Siphonaptera; most modified members of other taxa, including Mecoptera, for example *Caurinus* in Boreidae). Polarity is not apparent.

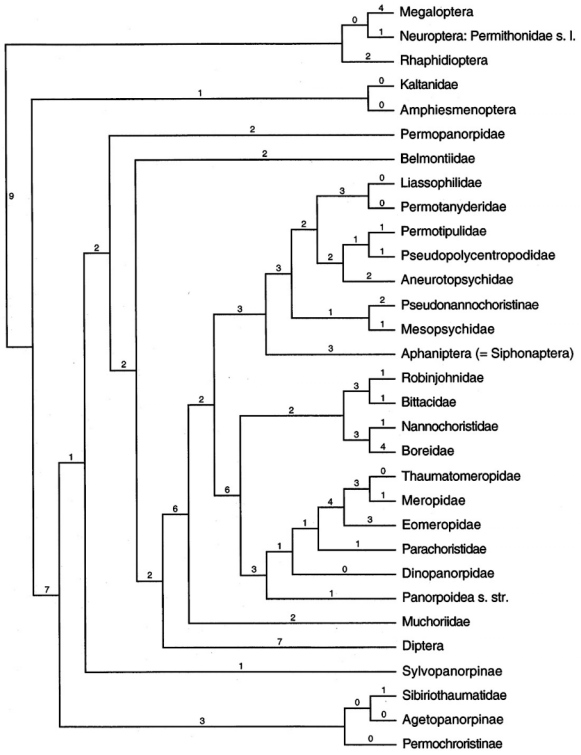
Table S5: Taxon–character-state data matrix (next page).

Character:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Megaloptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	–	0	0	0	0	p	1	0	0	1	1	0	p	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	p	0	0	1	0	0
Raphidioptera	0	0	0	0	0	0	0	0	0	0	0	0	0	p	0	0	0	0	0	–	0	0	0	0	–	?	0	0	p	p	0	1	0	p	0	p	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0
Permithonidae *sensu lato*	?	?	?	?	0	0	0	?	0	?	0	0	0	0	1	0	0	0	0	–	0	0	0	p	0	?	0	0	p	p	0	p	0	p	p	0	0	0	0	0	?	0	0	0	?	?	?	?	?	?	?	?	?
Kaltanidae	?	?	?	?	0	?	?	?	?	?	0	0	0	0	0	0	0	0	0	–	1	0	0	0	0	0	0	0	p	0	1	p	0	0	0	0	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Permopanorpidae	?	0	?	?	0	?	?	?	0	?	0	0	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	1	0	0	?	?	?	?	?	?	0	?	?	?	?	?	?
Belmontiidae	?	?	?	?	?	?	?	?	?	?	0	0	0	1	0	0	1	0	p	?	1	0	0	0	0	0	1	0	1	1	2	0	0	0	0	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Liassophilidae	?	?	?	?	?	?	?	?	?	?	0	1	1	1	0	0	1	1	1	–	1	p	1	0	–	1	1	0	1	1	1	0	0	1	0	1	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Permotanyderidae	?	?	?	?	?	?	?	?	?	?	0	1	1	1	0	0	1	1	1	1	1	1	1	0	–	1	?	0	1	1	1	0	0	p	0	1	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Robinjohniidae	?	?	?	?	?	?	?	?	?	?	0	0	0	1	0	1	1	1	1	0	1	0	1	0	–	1	0	0	1	1	?	1	1	1	–	1	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Permotipulidae	?	?	?	?	?	?	?	?	?	?	0	1	0	1	0	1	1	1	1	1	1	0	1	1	–	1	0	0	1	1	1	1	0	1	–	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Nannochoristidae	1	1	1	1	0	0	1	1	0	1	0	0	0	0	p	0	1	1	0	–	1	0	1	0	–	1	0	0	1	1	1	1	1	1	–	1	1	1	0	0	1	1	1	1	0	0	?	1	0	0	0	1	1
Thaumatomeropidae	?	?	?	?	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0	–	1	0	0	0	1	0	0	0	0	0	0	p	0	1	0	p	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Boreidae	1	p	?	1	0	0	1	1	0	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	1	1	p	1	1	0	1	?	1	1	1	0	1	p
Sibiriothaumatidae	?	?	?	?	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0	–	1	0	1	0	–	1	1	0	1	0	1	0	0	0	0	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Sylvopanorpinae	?	?	?	?	0	?	?	?	0	?	0	0	0	0	0	0	1	p	0	–	1	0	0	0	0	0	?	0	0	0	?	0	0	0	0	1	1	1	0	0	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Agetopanorpinae	?	?	?	?	0	0	?	?	0	?	0	0	0	0	0	0	1	p	0	–	1	0	p	0	–	?	1	0	?	0	1	0	0	0	0	1	1	1	0	0	?	0	0	1	?	0	0	?	?	?	?	?	?	?
Permochoristinae	?	?	?	?	0	0	?	?	0	?	0	0	0	p	0	0	1	p	p	0	1	0	1	0	–	1	1	0	1	?	1	p	0	p	0	1	1	1	?	0	?	?	0	?	?	?	0	?	?	?	?	?	?	?
Pseudonannochoristinae	?	?	?	?	?	?	?	?	?	?	0	0	0	0	0	0	1	1	p	0	1	0	1	1	–	1	2	0	1	p	1	1	0	1	?	1	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Mesopsychidae	?	0	?	2	1	1	?	2	1	?	0	0	0	0	0	0	1	1	p	0	1	0	1	0	–	1	1	0	1	1	1	p	0	1	0	1	1	0	2	0	?	?	?	?	?	0	0	?	?	?	?	?	?
Pseudopolycentropodidae	1	0	?	2	1	1	?	2	1	?	0	1	1	1	0	1	1	1	1	1	1	0	1	0	–	1	0	0	1	p	1	1	0	1	–	1	1	0	2	0	?	?	1	?	?	?	0	?	?	?	?	?	?
Aneuretopsychidae	1	?	?	2	1	2	?	2	1	?	0	?	0	1	0	0	p	p	p	p	1	p	1	0	–	1	0	0	1	1	1	1	0	1	0	1	1	?	1	0	?	?	?	?	?	0	?	?	?	?	?	?	?
Meropeidae	1	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	–	1	0	0	0	1	1	0	0	0	0	0	1	0	1	–	1	1	1	0	0	1	1	1	1	1	1	1	?	?	?	?	?	?
Parachoristidae	?	?	?	?	0	0	?	?	0	?	0	0	0	0	0	0	1	1	0	–	1	0	0	0	1	1	1	0	1	0	1	?	0	0	0	1	1	1	1	0	?	?	?	?	?	?	?	?	?	?	?	?	?
Bittacidae	1	1	1	1	0	0	1	1	0	1	p	0	0	1	0	1	1	1	1	1	1	0	1	0	–	1	0	1	1	p	1	1	1	1	?	1	1	1	1	0	0	0	0	0	1	1	0	0	0	1	1	1	1
Muchoriidae	?	?	?	?	?	?	?	?	?	?	0	0	0	0	0	1	1	1	1	1	1	0	1	0	?	1	1	0	1	1	1	0	0	0	1	1	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Dinopanorpidae	?	?	?	?	0	0	?	?	0	?	0	0	0	0	0	0	1	1	1	1	1	0	0	0	1	1	?	0	1	0	?	1	0	0	–	1	1	1	0	0	?	?	?	?	?	?	?	?	?	?	?	?	?
Eomeropidae	1	1	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	–	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	1	1	1	3	0	1	1	1	1	1	1	0	?	?	?	?	?
Panorpoidea *sensu stricto*	1	1	1	1	0	0	1	1	0	1	p	0	0	0	0	p	p	1	1	p	1	0	0	0	1	1	1	0	1	1	1	p	0	0	1	1	1	1	1	0	1	1	1	p	1	1	1	0	0	0	0	1	1
Amphiesmenoptera	1	0	0	p	p	0	0	0	0	1	0	p	p	p	p	p	0	0	0	p	1	p	0	0	p	p	p	0	p	p	1	p	p	p	?	0	1	1	0	0	0	0	0	0	0	p	0	0	p	1	1	0	p
Diptera	1	0	0	2	p	0	0	1	1	1	p	2	0	1	0	?	1	1	1	1	1	1	1	0	–	0	0	1	1	1	0	0	0	0	?	1	1	?	0	p	0	p	0	0	1	0	0	0	1	0	–	1	2
Siphonaptera	1	0	1	2	1	0	1	p	0	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	1	1	0	0	0	?	0	0	p	0	1	–	1	2

Figure S1: Best supported trees

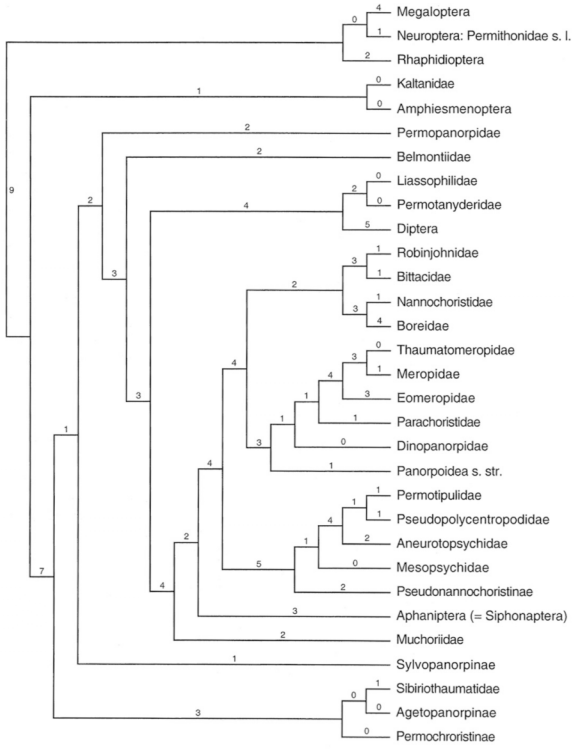
Heuristic search, misc. options

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CI = 0.525, RC = 0.383, Gfit = -41.904



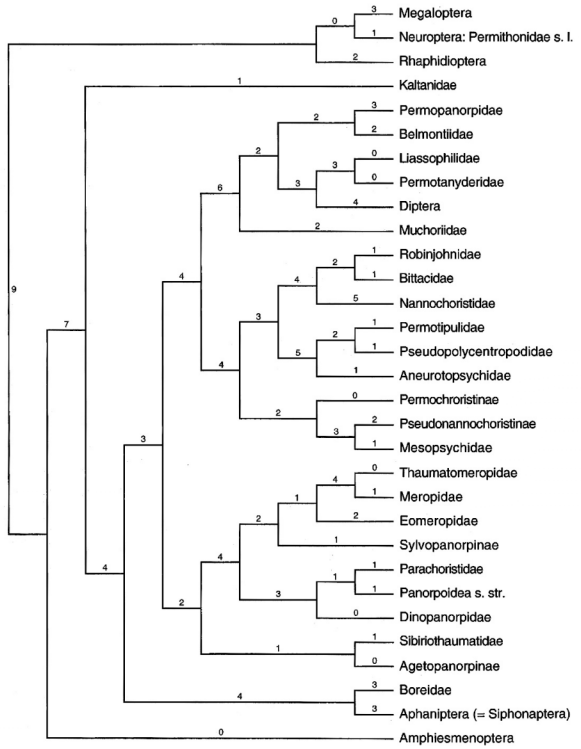
Heuristic search, general options

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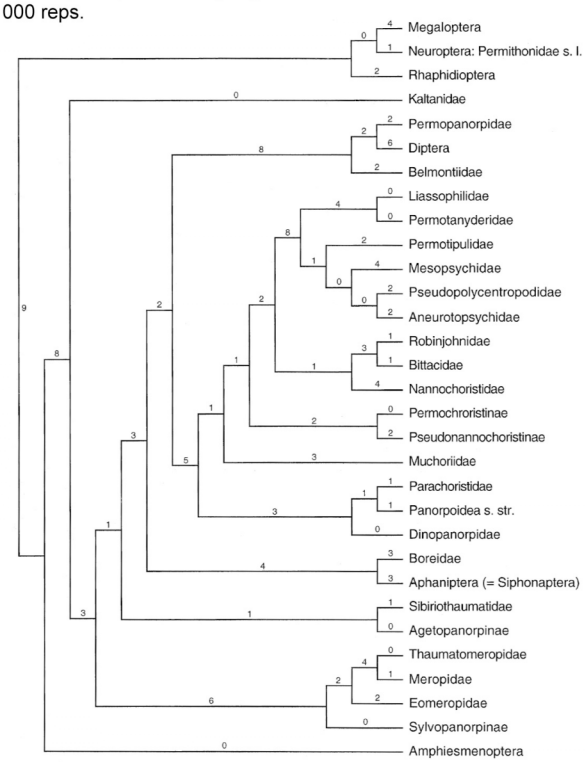
Bootstrap, no resampling, fast stepwise, compa 50% majority

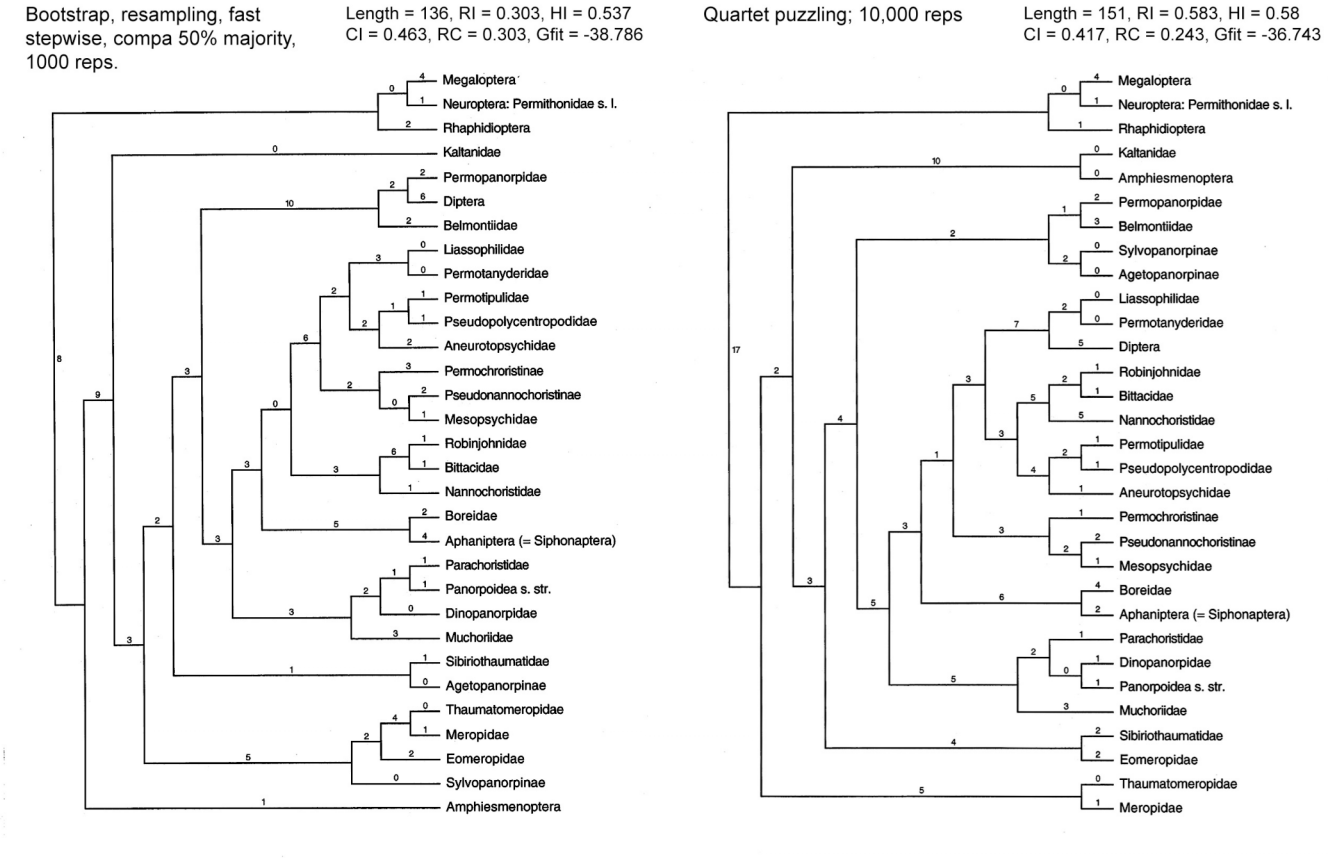
Length = 133, RI = 0.668, HI = 0.526
CI = 0.473, RC = 0.316, Gfit = -40.008



Jacknife, 50% deletion, fast stepwise, compa 50% majority, 1000 reps.

Length = 134, RI = 0.312, HI = 0.530
CI = 0.470, RC = 0.312, Gfit = -39.411





Examination of Insect Body Surfaces for Pollen

We searched for pollen adherent on insects, including heads and mouthparts, using a Zeiss Stemi SV II dissecting microscope and a Zeiss Axioskop epifluorescence microscope, the latter outfitted with an EFGP longpass filter cube set (exciter HQ470/40x, dichroic Q495LP, emitter HQ500LP (Chroma 41018). As a control, Jurassic pollen samples from the Hulett Sandstone, Wyoming, and Morrison Formation, Utah, both of low metamorphic grade, were observed to autofluoresce a soft, orange-pink color. Devonian age spores of higher metamorphic grade did not autofluoresce. By contrast, no pollen could be recognized in any of the insect specimens examined, or their surrounding matrix, including the Burmese amber specimen.

Geochemical Analyses of the *Jeholopsyche liaoningensis* Specimen

Geochemical identification of the food source of *Jeholopsyche liaoningensis* (Fig. 2A–E, Appendix S1) is important for understanding the feeding mode of this aneuretopsychid scorpionfly specimen (CNU-M-LB2005-002). The specimen (Fig. S2, A) shows in high-resolution backscattered electron images (BSEI) two splotches of dark, opaque matter lodged in the food canal, one terminally within the functional mouth (Fig. S2, B: lower square, F) and the other about 2/3 from the siphon tip (Fig. S2, B: upper square, J). For controls, we also examined the right metathoracic leg (Fig. S2, N,O) and matrix adjacent the proboscis (Fig. S2, B). An analyses of these two plugs was performed on an uncoated sample with an electron microprobe

(JEOL JXA–8900R WE/ED combined microanalyzer) and a FEI NOVA nannoSEM 600 FEG Variable Pressure Scanning Electron Microscope, using energy dispersive spectrometry (EDS) in both instruments. Initially in the study, numerous point analyses were performed with the electron microprobe in order to establish differences between the hindleg exoskeleton and the plugs of organic matter in the food canal, as well as distinguishing these three biological sites from adjacent rock matrix. Two elements were of particular interest, iron (Fe), as an indicator of blood hemoglobin, and sulfur (S) as an indicator of S-bearing amino acids that may occur in pollination drops (*21*,*22*). The electron microprobe in EDS mode was used to perform point analyses because it allowed higher beam currents that were not possible with the field emission SEM, and necessary to produce sufficient intensity for X-ray lines of minor elements such as S. Although the specimen was uncoated, conductivity was sufficiently strong to allow robust analysis of the sample.

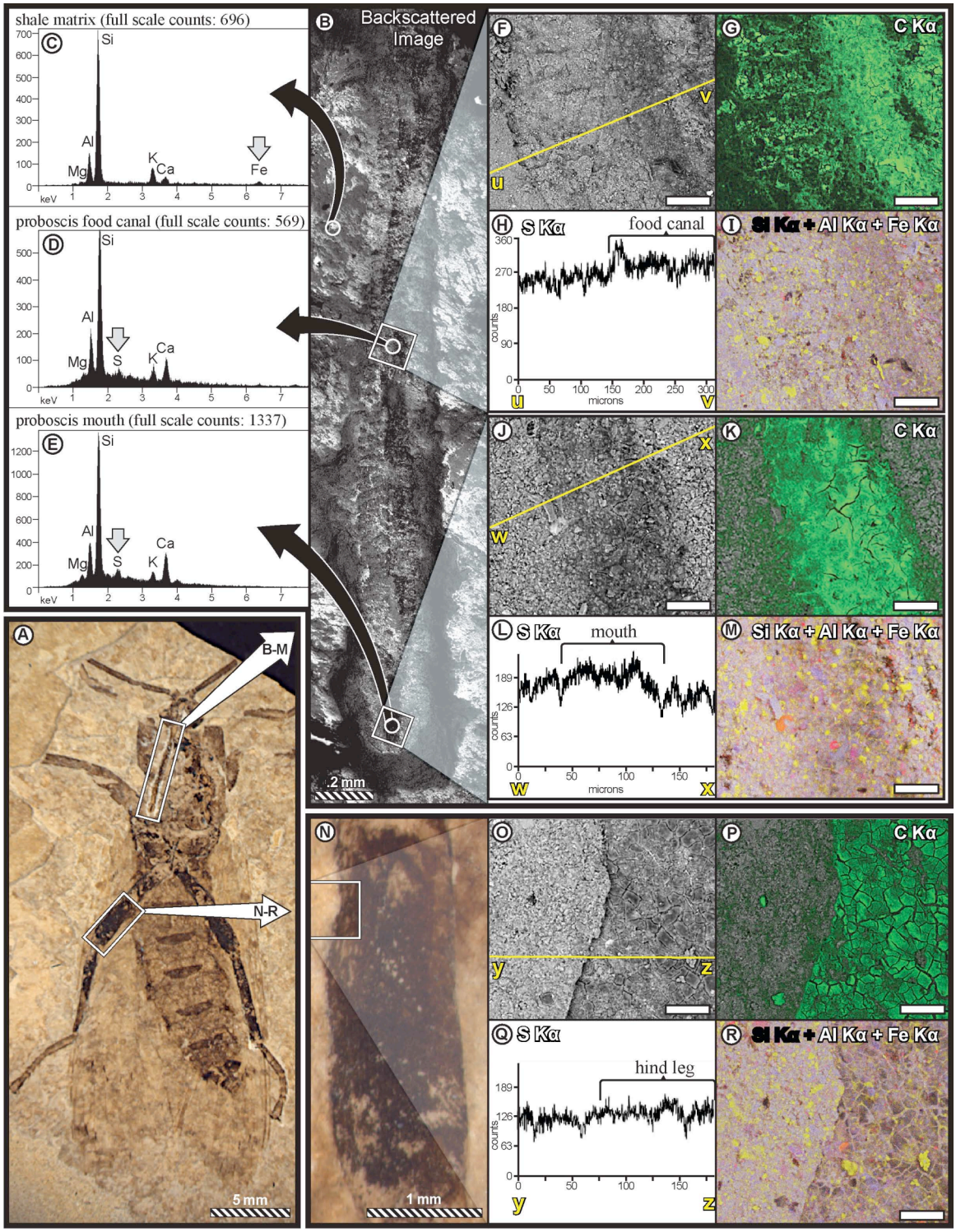
The above analyses (EDS) indicate the presence of somewhat elevated level of S in the two siphonal plugs (Fig. S2, D,E), but none in the matrix (Fig. S2C). In the next step, there was collection of BSEI images (Fig S2, F,J,O) and acquisition of X-ray maps with the field emission SEM (EDS mode) for the two siphonal plugs and hindleg, acquired under low vacuum at 15 kV, a beam current of about 3 nA and a pressure of 10 mbars. Intensities were obtained during 15 hours for each map. A full spectrum was collected for each pixel in a map with resolution of 1024 x 1024 pixels (~10^6 total pixels). Areas were selected to collect maximum intensity in a sufficiently large area to map representative portions of anatomically distinct areas of the fossil and surrounding matrix. The first of these map sets show the distribution of carbon (C), as a C Kα distribution, in the mid-siphon and mouth plugs and hindleg (Fig. S2, G,K,P, respectively). The second map set (Fig. S2, I,M,R) is a series of composite images for silicon (Si), aluminum (Al) and Fe, as Si Kα distributions for example. The composite series indicate mineral phases that contain Si, Al and Fe, with each color representing the same mineral phase. The C map shows that the carbonized layers on the examined siphon are very thin.

The results obtained in these analyses indicate the Fe is present only with associated phases of the sedimentary matrix and is incompatible with a blood source in the food canal or mouth. A slightly elevated level of S was found in the food canal and mouth (Fig. S2, H,L) in traverses extracted from the S Kα map in a band that corresponds to 10 percent of the map pixels. These S levels could be attributable to degraded organic plant constituents and thus interpreted as representing originally S-bearing amino acids or other biomolecules with outward diffusion into the lateral margin of the siphon. However, the evidence for this interpretation is minimal. By contrast, S levels for the hindleg and adjacent matrix (Fig. 2S, Q) exhibits no detectible elevation associated with the high C areas. It should be noted that in this specimen there is evidence for degradation of the carbon-rich material in both the siphon and mouth as well as the hindleg, representing diagenetic remobilization and diffusion. Use of Raman spectrometry or secondary ion mass spectrometry may provide critical data regarding organic compound structure found in the food canal plugs.

Figure S2: Mouthpart Geochemical Analyses

Geochemical data from the proboscis, food-canal and mouth contents, right metathoracic hindleg, and surrounding matrix of *Jeholopsyche liaoningensis* (CNU-M-LB2005-002). (See text for details of instrumentation and methodology.) A light-microscopy image of the examined aneuretopsychid scorpionfly is shown in (**A**). The upper rectangular template shows the examined proboscis, enlarged as a backscattered electron image (BSEI) in (**B**), showing target areas of analysis magnified in (**F**) for the mid-proboscis plug, and (**J**) for the mouth plug. Point analysis results by electron microprobe in EDS mode is given for the matrix (**C**), mid-siphon food tube in (**D**), and mouth plug in (**E**). The specimen's leg in (**A**) is enlarged as a light-microscopy image in (**N**), and a BSEI in (**O**). Carbon maps, illustrating C Kα abundance, proportional to the intensity of green, are shown for the mid-siphon plug (**G**), mouth (**K**) and matrix/hindleg (**P**). Sulfur (S) data extracted from the S Kα map (not displayed) taken from rectangular envelopes along indicated traverses (in yellow). The mid-siphon plug in (**H**) displays S abundance, taken from a rectangular area paralleling traverse u–y in (F). Similarly, S data for the mouth in (**L**) is taken from the surrounding rectangular area along traverse w–x in (J); and the matrix/hindleg area in (**Q**) is taken from the rectangular area adjacent traverse y–z in (O). Composite maps, built over the individual Si Kα (yellow), Al Kα (blue) and Fe Kα (red) maps, illustrate mineral phases in the matrix for the mid-siphon plug (**I**), mouth (**M**) and matrix/hindleg (**R**). Each color represents the same mineral phase throughout the composite maps. White bar scales at lower-right indicate 0.01 mm.

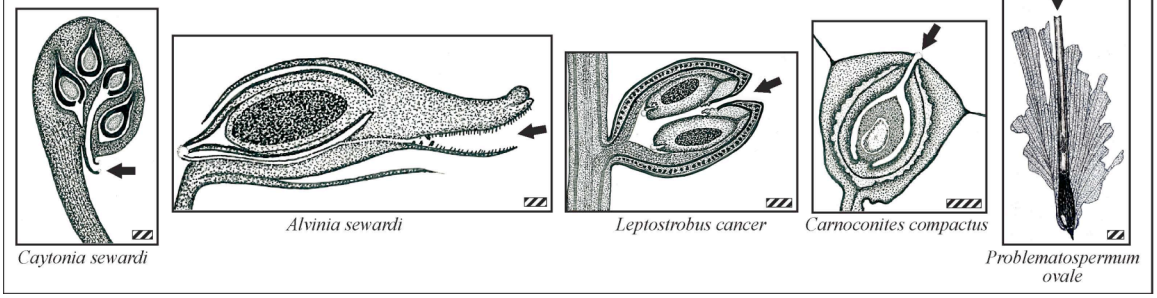
Figure S2: Proboscis, leg and matrix geochemical analysis



ANATOMY AND BIOLOGY OF RELEVANT MID-MESOZOIC OVULATE STRUCTURES

Table S6. Mid Mesozoic seed plants likely targeted by long-proboscid scorpionflies.

Right Panel Fig. 3, (Family), age	*Locality*	*Ovulate organ*	*Distance and width of conduit from aperture entry to pollen chamber*	*Pollen organ*	*Pollen diameter and clumping*	*Foliage*	*References*
Caytoniaceae Middle Jurassic (Bajocian)	Yorkshire, U.K.	*Caytonia sewardi* Harris	Decurved **tube** in cupule tissue, representing micropyle extension; 4 mm long by 0.5 mm diameter.	*Caytonianthus arberi* (Thomas) Harris	*Vitreisporites* (20–30 µm)	*Sagenopteris colpode*s Harris	[*S23, S24, S25, S26*]
Cheirolepidiaceae Republic; early Late Cretaceous (Cenomanian)	Pecinov, Czech Republic	*Alvinia bohemica* Kvaček	12 mm long distal **funnel** from 2 mm outer diameter to 0.3 mm inner orifice diameter, connecting to a **pipe** emerging proximally and adjacent to adaxial micropyle.	*Frenelopsis alata* (Feistmantel) Knobloch	*Classopollis* (32–65 µm) clumped	*Frenelopsis alata* (Feistmantl) Knobloch	[*S24, S27, S28*]
Czekanowskiaceae Middle Jurassic (Bajocian)	Yorkshire, U.K.	*Leptostrobus cancer* Harris	4.5 mm long interovulate **channel** expressed on both inner surfaces of a bivalved "capsule," with entry along the margin.	*?Ixostrobus* (Phillips) Harris	*Cycadopites* (35–40 µm)	*Solenites vimineus* (Phillips) Harris	[*S24, S29*]
Pentoxylaceae Early Cretaceous (Berriasian)	Bihar, India	*Carnoconites compactus* Srivastava	Rather diminutive **micropyle** and **salpinx** tube, 2 mm maximum length by 0.1 mm diameter.	*Sahnia nipaniensis* Vishnu-Mittre	*Cycadopites* (17–22 µm)	*Nympaniophyllum hobsoni* Bose, Pal & Harris	[*S24, S30, S31, S32*]
Gnetales unassigned family (Callovian, Kimmeridgian)	Daohugou, China; Karatau, Kazakhsan	*Problemato-spermum ovale* Turutanova-Ketova	Elongate, linear, tubular micropyle (**pappus tube**) about 12 mm long, extending from ovule proper; surrounded by a funelliform, papery, microveined structure.	unknown	unknown	unknown	[*S33, S34*]



SYSTEMATIC PALEONTOLOGY

Appendix S1: New Species Descriptions

Family Mesopsychidae Tillyard, 1917 (*S34*). **Type genus**: *Mesopsyche* Tillyard, 1917 (*S35*). **Other genera included**: Six previously known (*S36*) and one new genus described herein. **Emended diagnosis*:*** Moderate-sized insects. Forewing length 22-30 mm. Adult with prognathous, siphonate mouthparts; proboscis prolonged and well-developed. Antenna distinctly short, apical segments very fine, forming an arista. Setae on the legs not arranged in rings. Both fore- and hindwings of similar shape and venation. Wings distinctly emarginate at CuP apex. Sc with one or more branches. Rs and MA bifurcating; MP 4-branched; CuA unbranched.

Genus: *Lichnomesopsyche* Ren, Labandeira and Shih, gen. nov. **Type of the species**: *Lichnomesopsyche gloriae*, gen. et sp. nov. **Other species included**: *L. daohugouensis* sp. nov. **Generic diagnosis**: Wings comparatively large and elongate. Wing posterior margin distinctly

emarginate at CuP apex. In forewing, Sc not beyond the MA bifurcation, with anterior branch located before MA, originating from Rs. Rs and MA fork almost simultaneously, each with two endings. MP originates from stem of MP+CuA somewhat before (more basally) than Rs+MA from R. Stem of MA rectilinear. First bifurcation of MP is basad of RS+MA bifurcation. For hindwing, Sc beyond the point of MA distinctly originating from Rs. MP originating from stem of MP+CuA more distal than Rs+MA from R. **Etymology**: The genus name is a combination of *Lichno*-(Greek, meaning beauty) and *Mesopsyche* (type genus of the family). Gender feminine. **Species**: *Lichnomesopsyche gloriae*, Ren, Labandeira and Shih, sp. nov. (Fig. 1, A–N). **Species diagnosis**: New species resembles *L. daohugouensis* sp. nov. in venational features, but differs from the latter by wings without circular pale spots. **Measurements** (mm): For Holotype, forewing length 25, width 7; body length (excluding antennae and proboscis) 28; proboscis length 10; antenna length (preserved in part) minimally 4. **Etymology**: The species name is dedicated to Gloria A. Shih for her care, support and encouragement to C-K. Shih for collecting and studying insect and plant fossils. **Referred material**: Holotype: CNU-M-NN2005020-1 and -2 (♀). Paratypes: CNU-M-NN2005021-1 and -2 (♂), CNU-M-NN2005024 (gender unknown), CNU-M-NN2005025-1 and -2 (♀), CNU-M-NN2005027-1 and -2 (gender unknown), and CNU-M-NN2005029 (gender unknown. **Repository**: All fossil specimens studied are curated in the Key Lab of Insect Evolution and Environmental Change, College of Life Science, Capital Normal University, in Beijing, China. **Species:** *Lichnomesopsyche daohugouensis* Ren, Labandeira and Shih, sp. nov. (Fig. S3, A,B). **Species diagnosis**: This species differs from *L. gloriae* by smaller size and wings with distinctive, circular, pale spots concentrated on the M and Cu wing region. **Measurements** (mm): Forewing length 22, width 6.5; body length (preserved part, excluding proboscis) at least 14; proboscis length 8.5. **Etymology**: The species name refers to the fossil locality. **Referred material**: Holotype, CNU-M-NN2005022-1 and -2 (gender unknown). **Repository**: All fossil specimens studied are curated in the Key Lab of Insect Evolution and Environmental Change, College of Life Science, Capital Normal University, in Beijing, China **Locality and Age**: All fossil specimens of *Lichnomesopsyche* studied here are collected from Daohugou Village, Shantou Township, Ningcheng County, Inner Mongolia, China; Jiulongshan Formation, of late Middle Jurassic (transitional Bathonian–Callovian) age.

Genus: *Vitimopsyche* Novokshonov and Sukatsheva 2001 (*S36*). **Type of the species**: *Vitimopsyche torta* Novokshonov and Sukatsheva 2001 (*S36*). **Emended generic diagnosis**: Wings comparatively large and broad; posterior margin distinctly emarginate at CuP apex. Forewing with long Sc, reaches far beyond the MA bifurcation. Rs forks very late, ending in two, very short veins. MA stem and MA1 branch form a distinctly S-shaped course. MP originates from stem of MP+CuA more basally than Rs+MA from R. The first bifurcation of MP is distad of RS+MA bifurcation. In hindwing, Sc extends far beyond the point where MA originates from Rs. MA stem and MA1 branch form a distinctly S-shaped trajectory. MP originates from stem of MP+CuA more basal than Rs+MA from R. **Species**: *Vitimopsyche kozlovi* Ren, Labandeira and Shih, sp. nov. (Fig. 1, O–R). **Species diagnosis**: This species differs from *V. torta* by Sc only with an anterior branch in forewing; Rs forks very late, ending in two, very short veins. **Measurements** (mm): Forewing length 24, width 8; proboscis length (preserved part) at least 8.5. **Etymology**: The specific name is dedicated to paleoentomologist M. V. Kozlov who, with A. Rasnitsyn, recognized the first fossil scorpionfly (*Aneuretopsyche rostrata*) with a long proboscis

in 1990 (*3*). **Referred material**: CNU-M-HP2005001-1 and -2 (gender unknown). **Locality and Age**: Shimen Village, Yangshulin Township, Pingquan County, Hebei Province, China; Yixian Formation, of Early Cretaceous (Barremian) age.

Family Pseudopolycentropodidae Handlirsch, 1925 (*S37*). **Type Genus**: *Pseudopolycentropus* Handlirsch, 1906 (*S38*). **Other genera included**: *Pseudopolycentropodes* Grimaldi and Fraser, 2005 (*S1*) and *Parapolycentropus* Grimaldi and Rasnitsyn, 2005 (*S1*).

Genus: *Pseudopolycentropus*, Handlirsch, 1906 (*S38*). **Type of the species**: *Phryganidium perlaeformis* Geinitz, 1884 (*S39*). **Other species included**: *P. triangularis* Handlirsch, 1925 (*S37*); *P. latipennis* Martynov, 1927 (*S40*); *P. obtusus* Bode, 1953 (*S41*); *P. prolatipennis* Whalley, 1985 (*S42*); *P. triasicus* Papier, Nel and Grauvogel-Stamm, 1996 (*S43*); *P. madygenicus* Novokshonov, 1997 (*S44*); *P. daohugouensis* Zhang, 2005 (*S1*); and two new species described herein. **Species**: *Pseudopolycentropus janeannae* Ren, Shih and Labandeira, sp. nov. (Fig. 2, J–L). **Species diagnosis**: In general venation *P. janeannae* somewhat resembles *P. latipennis* Martynov, 1927 (*S40*), but differs from the latter by broad forewing (length/width ratio from 2.0:1 to 2.3:1); apex of Sc extends to level of Rs origin; crossvein c–r perpendicular to adjoining longitudinal veins; crossvein m–cua closer to basal dc cell; crossvein a_1–a_2 basal to cup–a_1; in hindwing Sc distinctly short. *P. janeannae* is distinguished from *P. daohugouensis* by following venational features: pterostigma well developed; M_{2+3} stem longer than that of *P. daohugouensis*; crossvein m–cua closer to basal dc cell; 5 stable crossveins distinctly present in both Cu and A area, versus one such crossvein in *P. daohugouensis*. **Measurements (mm)**: Holotype forewing length 8, width 4; body length (excluding antennae and proboscis) 7. Proboscis length 1.63 for Paratype CNU-M-NN2005030-1. **Etymology**: The species name is dedicated to Jane Ann Shih, daughter of C.-K. Shih, for demonstrating initiative, caring and leadership in her study and work, and for providing inspiration and support to paleontology. **Referred material**: Holotype: CNU-M-NN2005001-1 and -2 (♀). Paratypes: CNU-M-NN2005030-1 and -2 (♀), CNU-M-NN2005003 (female), CNU-M-NN2005004-1 and -2 (♂), CNU-M-NN2005031-1 and -2 (gender unknown). **Species**: *Pseudopolycentropus novokshonovi* Ren, Shih and Labandeira, sp. nov. (Fig. 1, F; Fig. S4, A,B). **Species diagnosis**: The new species is distinct from all Jurassic species of the genus by crossvein c–r becoming oblique inwardly; crossvein cup–a_1 connected with basal crossvein cua–cup, virtually in line with each other; posterior wing margin distinctly concave. **Measurements (mm)**: Holotype forewing length 8, width 3.9; body length (excluding antennae and proboscis) 7; antenna length (preserved part) at least 3; proboscis length 1.5. **Etymology**: The species is named in honor of Russian paleoentomologist V. G. Novokshonov. **Referred material**: Holotype: CNU-M-NN2005002 (♀). **Locality and Age**: Same as that for *Lichnomesopsyche gloriae* and *daohugouensis*.

Family Aneuretopsychidae Rasnitsyn and Kozlov, 1990 (*S3*). **Type genus**: *Aneuretopsyche* Rasnitsyn and Kozlov, 1990 (*S3*). **Other genera included**: One new genus described herein. **Emended diagnosis**: Moderately sized insects; opisthognathous mouthparts; adults possess a remarkably prolonged siphonate proboscis, with its annulate exterior covered by well-developed dense setae or microtrichia. Antennae multiarticulate, covered with annulate setae, distinctly longer than proboscis. Forewing elongate. Sc with multiple branches. Both Rs and MA

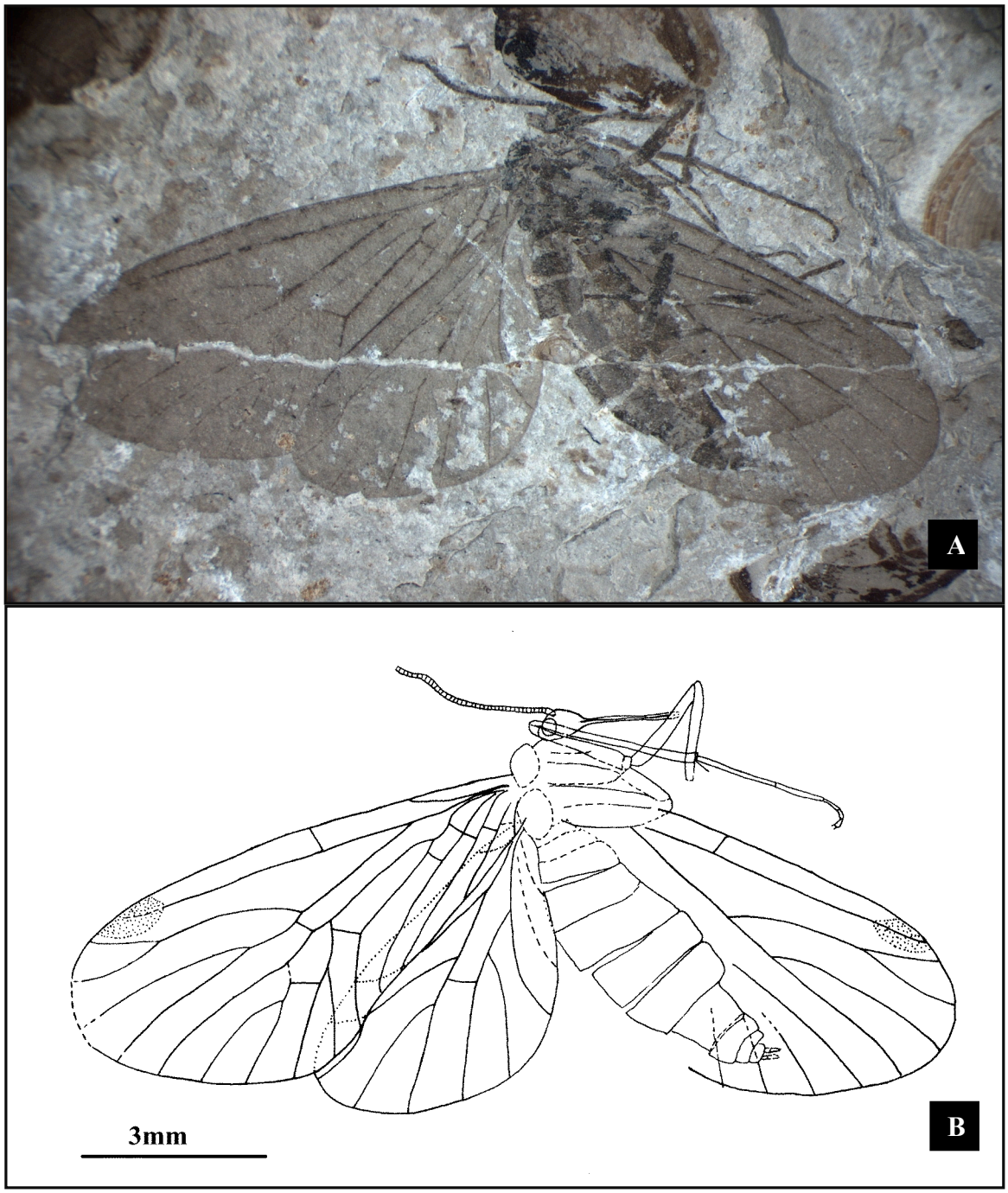
bifurcating. MP 4-branched. CuA single or probably bifurcating. Hindwing distinctly broader than forewing. Setae on legs arranged in rings.

Genus: *Jeholopsyche* Ren, Shih and Labandeira, gen. nov. **Type of the species**: *Jeholopsyche liaoningensis* gen. et sp. nov. **Other species included**: Type species only. **Generic diagnosis**: Forewing Sc with three branches. R1 unbranched. MP originates from stem of MP+CuA before (more basal) than Rs+MA from R. RS+MA bifurcation distinctly basad of first bifurcation of MP. Both fore- and mid basitarsus shorter than remaining four segments in combined length. Basitarsus of hind legs almost equal to remaining four segments in combined length. **Etymology:** The genus name is derived from the Jehol Biota, where this genus originates. Gender feminine. **Species**: *Jeholopsyche liaoningensis* Ren, Shih and Labandeira, sp. nov. (Fig. 2, A–E; Fig. 2S, A–R). **Species diagnosis**: Same as that of the genus. **Measurements (mm)**: Forewing length (preserved part) at least 21.5, width 6; body length (excluding antennae and proboscis) at least 23; proboscis length 6.8; antenna length (preserved part) at least 10. **Etymology**: Species name is referred to Liaoning Province, where the fossil was collected. **Referred material**: Holotype: CNU-M-LB2005002-1 and -2 (♂). **Locality and Age**: Huangbanjiguo Village, Shangyuan Township, Beipiao City, Liaoning Province, China. Yixian Formation, of Early Cretaceous (Barremian) age.

Figure S3: *Lichnomesopsyche daohugouensis*



Figure S3: *Pseudopolycentropus novokshonovi*



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