

ELECTRONIC APPENDIX

This is the Electronic Appendix to the article

Synergistic effects of combining morphological and molecular data in resolving
the phylogeny of butterflies and skippers

by

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Electronic appendices are refereed with the text; however, no attempt is made
to impose a uniform editorial style on the electronic appendices.

Electronic Appendix. Morphological character matrix based largely on the published matrix by de Jong *et al.* (1996). Character descriptions follow the matrix. Several of the characters in de Jong *et al.* (1996) have been combined in our study: their 10 and 11 to form our 9, 30 and 31 to form 28, 32 and 33 to form 29, and 75 and 76 to form 71.

	0	1	2	3	4	5	6	7	8	9
Pyralis	0002000000	021-300000	0001020000	1020000010	0000000000	0?00100100	0000100000	0000000000	0000000000	000000100
Urania	0001220122	2201000310	0001002002	0010001010	0000000000	0000100100	2000?00001	0001000200	003----000	00000001?
Archiearis	0013020101	0002000200	0003001101	0000000010	0000000000	0000001000	0100100000	0201000200	000-000000	0000000000
Othreis	0002000000	2201101000	0002000112	1000000010	0000000000	0200100100	0000000000	0110000200	000-200000	0000000110
Macrosoma	0102000101	1101100000	0000000100	0000000010	0011001100	0201000000	0000000001	0000010000	000----000	000010011
Pyrgus	0000000101	0010000300	0210100140	1000000010	0000000000	0000101110	1001000100	2010110102	0010000001	010010210
Urbanus	0000000101	0000000300	0020101140	1001000010	0000000000	0000100110	2001000100	2020110102	0010000001	01001021?
Bibasis	0000000101	0000000300	0000102142	1000000010	0000000000	0000101110	2001000000	2020110102	0010000001	01001001?
Hesperia	0000000-01	0110000300	0020101040	1000000010	0010000000	0010100110	1001000100	2020110102	0011001001	010010210
Trapezites	0000000101	0010100300	0010100140	1000000010	0000000000	0000100110	2001000100	2010000102	0010000001	01001021?
Pyrrhopyge	0000000101	0100000300	0020100140	1000000010	0000000000	0000100010	2001000000	2020110102	0010000001	0100202??
Baronia	2012000000	0000200300	0100000521	0000000010	0020020000	1222000201	1010010000	1201000202	1021210002	001110001?
Papilio	0001000020	0000200310	0100000420	0000001110	0020020010	2222000201	1010010000	1201000202	102-210012	001110011
Graphium	2001000020	0000200311	0100000421	0000010010	0020020010	2222000201	1000010000	1201000202	102-210012	001110011
Troides	0002000020	0100220311	0100000420	0000000010	0020020010	2222000201	1010020000	1201000202	102-210012	001110011
Parnassius	0012020000	0200200310	0100000200	0000000010	00200220-0	-222000201	2000010000	0001000202	1020110012	001110010
Dismorphia	-003010000	0200300300	0103000300	0000000010	0110000001	2010300200	1000050000	0200001211	013-210002	001110011
Eurema	0012020100	0202000300	0100000100	0000000010	0120020001	0022000200	1000040001	0000001211	013-210002	001110011
Colias	0013020100	1202000300	0100000000	0110000010	0120020001	2222000200	1000040000	0000001211	013-210002	001110011
Delias	0003020100	0000000300	0100000400	0000000010	0120020001	0022000200	1000040000	0000001211	013-210002	001110011
Pieris	0012020100	0001000300	0100000400	0020000010	0120020001	0012000200	1000040000	0000001211	013-210002	001110011
Pseudopontia	0112030102	-000000030	0110000430	00-0000010	0120011101	0221300200	00-0040000	0200001211	013-210002	0011100?1
Liptena	0002000102	0202000300	0100003002	1000000011	1112003000	0210300200	1000000001	0000000200	003-212102	0011110?2
Poritia	2012010102	0101000300	0100001002	1000000011	1112003000	0210300200	1000000001	0000000201	0031012102	0011110?2
Liphyra	0002020100	0101000300	0000001000	0010000110	0110000000	2010300200	1000000001	0000000100	0031112102	001111010
Miletus	0012020102	0101000300	0110001002	1000000011	0102004000	0200300200	1000000001	0100000201	0031112102	001111011
Curetis	0012000100	0101000300	0200002002	1000000011	2112004000	0000010200	1000000011	0000000201	0031012102	001111011
Eumaeus	00120-0100	0000000300	0100000101	0000000011	0112004000	0010010200	1000000011	0000000201	003-212102	001111011
Lucia	0012020100	0100000300	0000000000	1000000011	0112?04000	0000000200	1000000001	0000000201	003-212102	0011110?0
Thecla	0012020100	0000000300	0000001000	1000100111	0112004000	0010010200	1000000011	0000000201	003-212102	101111010
Anthene	0012000100	0000000300	0000001002	1000000011	0102014000	0000010200	1000000011	0000000201	003-212102	1011110??
Polyommatus	0012000100	0010000300	0100001000	1000000011	0112004000	0010000200	1000000011	0000000201	003-212102	101111011
Lycaena	0012000100	0010000300	0100001002	1000100111	0112004000	0010000200	1000000001	0000000201	003-212102	101111011
Styx	0003-20100	2202000300	01--002350	0000000011	1111003000	0210300200	1000000011	0200000201	002-212102	00111101?
Emesis	0012010100	0202000300	0200000402	1000000011	2101003000	0110200200	1000000001	0000000201	002-212102	001111011
Euselasia	0012020102	1201400300	0100000102	1020000010	3102003000	0100200200	1000000001	0200000201	002-212102	001111011
Riodina	00120-0102	0212000300	0210001402	100000001?	3112003100	0?10210200	1000000011	0000000201	002-212102	0011110?1
Hamearis	00-3010100	0202000300	0103000402	0000000011	3102003000	0210300200	1000000011	0000000201	002-212102	001111011
Libythea	00020-0110	1101000300	0100001400	0000000011	0101003000	0?00010200	1000031000	0100010201	0031112102	111111012
Danaus	0002000110	2100000300	0100000211	0010000012	0102103310	0210000200	1010021000	0000000201	0021110102	001111012
Heliconius	0003000120	2102300300	0100000302	0020000012	0102003300	0022010200	1000031000	0000000201	0031110102	001111012
Acraea	0003000100	1201400300	0102000400	0020000012	0112003300	2222000200	1000021000	0000000201	0031110102	001111012
Argynnis	0002000110	1201300300	0100001402	0020000012	0112003300	0022010200	1000031000	0000000201	0031110102	001111012
Nymphalis	0102000100	0201400300	0100001202	0020000112	0111003300	0020010200	1000031010	0100000202	0031110102	001111012
Melitaea	0103000100	1201400300	0102001402	2--0000012	0102003300	2020000200	1000021000	0000000202	0031110102	001111012
Colobura	0002000112	1002300300	0100001200	0010000112	0102003300	0020010200	1000031000	0000000202	0031110102	001111012

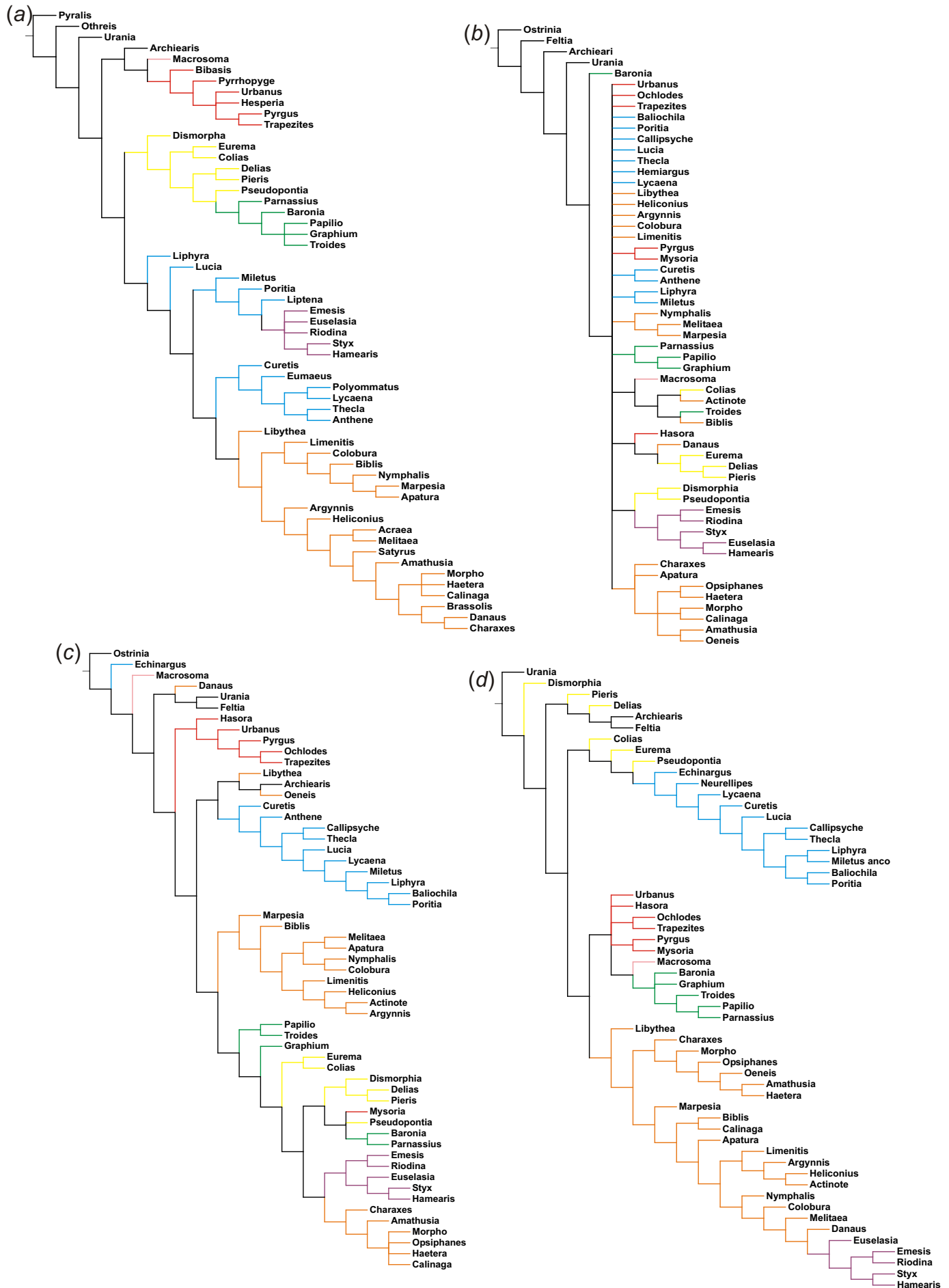
Limenitis	0002000110	1200300300	010-0--41-	2--0000112	0102003300	0021010200	1000031000	0000000202	0031110102	001111012
Biblis	0202000112	0201300300	010-0--20-	2--0000012	0102003300	0021010200	1000031001	0000000202	0031110102	001111012
Marpesia	0003000102	--2-400300	010-0--40-	2--0001112	0102003300	0020010200	1000031000	0000000202	0031110102	0011110?2
Charaxes	0002000122	0001300300	0100003512	-010101012	0102003300	0020010200	1000021010	0000000201	0021110102	001111012
Apatura	0102000102	--2-400300	010-0--40-	2--0000012	0102003300	0020010200	1000031000	0000000201	0021110102	001111012
Morpho	0002000121	0200410300	010-0--31-	2--0000012	0112013300	0022010200	1010031000	0000000201	0021110102	001111012
Amathusia	0003000122	0002400300	010-0--30-	2--0000012	0102003300	0021010200	1010031000	0000000201	0021112102	0011110?2
Brassolis	00020-0120	0000400300	0100000321	0020000012	0102003300	0022310200	1010031000	0000000201	0021110102	001111012
Satyrus	0203000110	1200400300	0100000400	0010000012	0102203300	0020010200	1000031000	0000000201	0021112102	001111010
Haetera	0202020111	1001010300	0100001120	0000000012	0102003300	0022310200	1010031000	0000000201	0021110102	0011110??
Calinaga	0002000120	0000310300	0100001310	0000000012	0102013000	0022000200	1010021010	0000000201	0021110102	001111012

Character descriptions

- 0 Forewing vein Sc: free to costa (0), fusing with R1 for short distance then separate to costa (1), fusing with R1 and then continuing so right to costa (2);
- 1 Forewing vein Sc: not thickened or swollen (0), thickened inflated (1);
- 2 Forewing radial system: with five branches (0), with less - four or three (1);
- 3 Number of forewing radial veins arising from discal cells: five (0), four (1), three (2), two (3);
- 4 Forewing vein M3: arising separately from discal cell (0), connate with Cula (1), stalked with Cula (2);
- 5 Forewing median veins: none arising from discal cell connate or fused with radial system (0), R5 and M1 connate (1), R5 and M1 stalked (2), R5, M1 and M2 stalked (3);
- 6 Forewing veins M2 and M3: arising separately from discal cell (0), almost connate (1);
- 7 Pattern of forewing cubital system: quadrifid (0), trifid (1);
- 8 Basal spur on forewing cubitus: absent (0), present as short process (1), present as a distinct spur (2);
- 9 Forewing discal cell: intermediate in size, 41-59% of wing length (0), long, 60% or more of wing length (1), short, 40% or less of wing length (2);
- 10 Forewing discocellular recurrent veins: absent (0), weakly indicated (1), distinctly present (2);
- 11 Forewing vein m1-m2: not incurved towards wing base (0), slightly incurved (1), incurved sharply angled (2);
- 12 Forewing discal cell: closed (0), weakly closed (1), open (2);
- 13 Forewing vein m2-m3: not incurved (0), slightly incurved (1), incurved (2);
- 14 Forewing posterior anal vein (2A): present, looped to anterior anal vein but without free tip (0), present, looped to anterior anal vein but with free tip (1), present, running free from anterior anal vein to margin or nearly present, but only as a basal spur (2), completely absent (3);
- 15 Anterior margin of anterior forewing anal vein (1A+2A): simple, smooth, without a spur or process (0), with a smooth swelling or process (1), with a distinct sub-basal spur (2);
- 16 Forewing areole: absent (0), present between veins R2 and R3 (1);
- 17 Retinaculum and frenulum: both present in both sexes (0), both present in males, but only frenulum in females (1), both present in males, but both absent in females (2), both absent in both sexes (3);
- 18 Hindwing vein 3A: present (0), absent (1);
- 19 Pocketed brush in anal cells of hindwing: absent (0), present (1);
- 20 Hindwing CuP: absent (0), present (1);
- 21 Humeral area of hindwing: thickened, 'thumb'-like (0), without marginal thickening or vein with short vein (1);
- 22 Median veins in hindwing: three veins present running to margin (0), M2 weak (1), only two M veins, ie M2 obsolete (2);
- 23 Hindwing median and radial systems: well separated (0), R5 and M1 very close (1), R5 and M1 connate R5 and M1 stalked (2);
- 24 Area of small specialized scales adjacent to humeral cell in hindwing: absent (0), present (1);
- 25 Hindwing M2 and M3: well separate (0), connate (1), stalked (2);
- 26 Hindwing M3 and Cula: well separate (0), connate (1), stalked (2);
- 27 Hindwing humeral vein: absent (0), short (1), longer, straight (2), longer, curved basally (3), longer, curved distally (4), long and forked (5);
- 28 Humeral cell of hindwing: shut (0), open, very small, level with or anterior to base Rs (1), larger, roughly square or rhomboid (2), long (3), open, very small semi-circular, or veins knotted, posterior to Rs (4);

- 29 Hindwing discal cell: intermediate, 41-59% of wing length (0), long, 60% or more of wing length (1), short, 40% or less of wing length (2);
- 30 Hindwing discal cell: strongly closed (0), weakly closed (1), open (2);
- 31 Recurrent veins on hindwing discocellulars: absent (0), present (1);
- 32 Hindwing cross-vein m1-m2: forming angle with M2 (0), curving into M2 smoothly (1), running more or less straight into M2 (2);
- 33 Hindwing vein 1A+2A forming a tail: absent (0), present (1);
- 34 Hindwing vein Culb forming a tail: absent (0), present (1);
- 35 Hindwing vein Cula forming a tail: absent (0), present (1);
- 36 Hindwing vein M3 forming a tail: absent (0), present (1);
- 37 Hindwing tornal lobe (margin of cell A2): absent (0), present (1);
- 38 Forewing long-vein CuP: present (0), absent (1);
- 39 Foreleg: not strongly reduced (0), strongly reduced in male, but less so in females (1), strongly reduced in both sexes (2);
- 40 Forecoxa terminal peg-like process extending beyond articulation with trochanter: absent (0), very small (1), large process in both sexes (2), very large process in males but absent in females (3);
- 41 Foreleg epiphysis: present (0), absent (1);
- 42 Fore-tibia spines: absent (0), few (1), many (2);
- 43 Male foreleg: with 5 tarsomeres (0), 2-4 tarsomeres (1), only 1 tarsomere (2);
- 44 Female foreleg: with 5 tarsomeres (0), 2-4 tarsomeres (1), only 1 tarsomere (2);
- 45 Dorsal spines on foreleg tarsomeres: absent (0), few (1), many (2);
- 46 Terminal structure of male foreleg: equal and unreduced claws (0), reduced claws (1), unequal claws (2), lacking claws and with terminal tarsal segment blunt or papillate (3), lacking claws and with terminal tarsal segment down curved to a point (4);
- 47 Terminal structure of female foreleg: equal and unreduced claws (0), reduced claws (1), unequal claws (2), lacking claws and with terminal tarsal segment blunt, clubbed or ankylose (3);
- 48 Claws of pterothoracic legs: curved (0), almost straight (1);
- 49 Claws of pterothoracic legs: simple (0), distinctly bifid (1);
- 50 Aroliar pad of claws of pterothoracic legs: present, well-developed (0), reduced (1), absent (2);
- 51 Pulvilli of claws of pterothoracic legs: present, well-developed (0), reduced (1), vestigial (2);
- 52 Spines on tibiae of pterothoracic legs: absent (0), few (1), many (2);
- 53 Dorsal spines on tarsi of pterothoracic legs: absent (0), few (1), many (2);
- 54 Hind tibia terminal spurs: paired equal or subequal (0), paired unequal (1), single (2), absent (3);
- 55 Mid tibia sub-basal scale brush: absent (0), present (1);
- 56 Male tibial hairpencil on hindleg: absent (0), present (1);
- 57 Hindleg mid-tibial spurs: equal (0), unequal (1), absent (2);
- 58 Mature larva 'neck': absent (0), present (1);
- 59 Larval osmeterium: absent (0), present (1);
- 60 Distal or subterminal part of antennal flagellum: not relatively thickened or clavate (0), more or less distinctly thickened or clavate (1), clavate with long apiculus (2);
- 61 Antennal segments: not distinctly serrate or pectinate (0), serrate in male or in both sexes (1), pectinate in male or in both sexes (2);
- 62 Antennal flagellum: scaled dorsally for most of length (0), largely bare dorsally, except in some cases at extreme base (1);
- 63 Antennal bases: relatively close (0), very wide apart (1);
- 64 Sexual dimorphism in antennae: not distinct (0), distinct (1);
- 65 Antennal segments: without lateral or mesial grooves or depressions (0), with more or less wide basal mesial depression (1), with paired lateral depressions (2), with paired lateral grooves (3), with a longitudinal mesial groove or depression (4), with three apical depressions (5);
- 66 Raised ventral carinae on antennal flagellum: absent (0), three carinae separating two grooves or paired depressions (1);
- 67 Lateral scale tuft ('eyelash') extending over eye from antennal base: absent (0), present (1);
- 68 Eye: apparently bare (0), conspicuously hairy (1);
- 69 Eye: entire, not emarginate (0), weakly to more strongly emarginate adjacent to insertion of antennae (1);
- 70 Eye ring: absent (0), partial glossy eye ring lacking distinct ommatidial facets (1), complete eye ring with distinct ommatidial facets (2);
- 71 Labial palp: average in length (0), very long (1), very short (2);

- 72 Second palpal segment, including investiture: narrow (0), thicker, noticeably wider than third segment (1), very wide, very much thicker than third segment (2);
- 73 Axillary 3: reaching forward not further than halfway to base of vein 1A+2A (0), reaching forward almost to or beyond anterior corner of 1A+2A (1);
- 74 Axillary 3: irregularly Y-shaped (0), differently shaped (1);
- 75 Outer margin of axillary 3: more or less straight or convex (0), strongly concave (1);
- 76 Outer margin of axillary 3: smooth, without any indentation or extension (0), with blunt tooth or indentation on which base of vein 1A+2A hinge (1);
- 77 Posterior part of axillary 3 connected: by ligament to base of jugum or thickening of hind margin of wing to base of vein 2A (0), axillary 3 lacking such a connection (1);
- 78 Median plate 1: free (0), fused with axillary 3 (1);
- 79 When viewed directly from above, median plate 2: almost completely visible (0), partly covered by base of vein 1A+2A (1), invisible or nearly so (2);
- 80 When viewed directly from above, radial plate: not covering part of axillary 2 and median plate 1 (0), raised and partly covering axillary 2 and median plate 1 (1);
- 81 Lateral plates of thoracic pronotum: fused mediodorsally (0), not fused (1);
- 82 Anepisternum of mesothorax: well-developed (one third to one half length of whole episternum) (0), small (one quarter or less of episternal length) (1), present only as a tiny sclerite not clearly discernible or absent (2);
- 83 Precoxal (paracoxal) and marginopleural sutures: not fused (0), fused (1);
- 84 Precoxal suture: reaching anterior margin of basisternum (delimiting triangular basisternum) (0), not reaching this far (1), not clearly discernible or absent (2);
- 85 Parepisternal suture: strongly curved before reaching margin of basisternum or co-linear (0), running in straight or smoothly curved line from dorsal end to base of spinasternum (1);
- 86 Parepisternal suture: well-developed (0), present only as a shallow depression (1), indistinct or absent (2);
- 87 Secondary sternopleural suture: absent (0), present (1);
- 88 Spinasternum: not produced laterally (0), produced laterally (1);
- 89 Mesophragma: without special structures (0), with indistinct dorsal plates or flat ridges (1), with dorsal processes (2);
- 90 Prescutum: oblique to almost vertical, with metanotum not appearing truncated (0), approximately vertical or with upper end slightly anterior to lower end, mesoscutum appearing truncated in lateral view (1);
- 91 Mesoscutellum: not overhanging metanotum (0), overhanging metanotum (1);
- 92 Tegulae attached to mesonotum by membrane: remote from ventral edge (0), at ventral edge (1);
- 93 Secondary sclerite posterior to metascutellum: absent (0), present (1);
- 94 Abdominal tergum I: flat or slightly domed plate (0), more or less inflated (1), compressed and tilted to an almost vertical position, scale-like (2);
- 95 Abdominal sternite II: without distinct anterior sclerite (at most slight sclerotization in membrane) (0), with narrow anterior sternite separated by weak sulcus (1);
- 96 Head chaetosemata: one pair (0), none (1), two pairs (2);
- 97 Egg: flat, with major axis horizontal (0), upright (1);
- 98 Pupa: not penduline or girdled (0), girdled (1), penduline (2);



Electronic Appendix. Results of separate cladistic analyses of the different data sets. (a) Morphology: strict consensus of 120 equally parsimonious trees, length = 506, CI = 0.32, RI = 0.68. (b) COI: strict consensus of 9 equally parsimonious trees, length = 4972, CI = 0.22, RI = 0.26. (c) EF-1a: strict consensus of 4 equally parsimonious trees, length = 4179, CI = 0.19, RI = 0.33. (d) Wingless: strict consensus of 3 equally parsimonious trees, length = 2508, CI = 0.20, RI = 0.44.