

Supplemental material 1

Coding for *Tegulariscaptor minor* gen. nov.

Coding based on Hooker (2016b) character matrix.

0?0?0?00?0 ??10031110 0000200??? ?001101?01 11121011?? ?????????? ??????12??
?????????? ????????121 2201010210 1211101112 ?????????? ?????????? ??????????
?????????? ?????????? ?????????? ?

Coding based on Schwermann & Thompson (2015) character matrix.

1?1?1?111? 2??0?01111 00111000?? ?001101?0 0011100??? ?????????? ??????????
?????????? ????????12 1220111021 011110121? ?????????? ?????????? ??????????
?????????? ?????????? ?????????? 111???

Character states at numbered nodes

The following numbered characters and their states relate to Hooker's (2016a, b) matrix. Plain type indicates homoplasy. Square brackets enclose character states found only by ACCTRAN optimization; parentheses enclose character states found only by DELTRAN optimization.

Synapomorphies: 19, 32, 35, 93, 104, 110 [24]

Hooker's (2016b) character list.

Teeth

1. First lower incisor, I₁, present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 1, coding reversed. N.B., the first lower incisor of soricids is identified as I₁ following Lopatin, 2006).
2. Third upper incisor, I₃, present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 2, coding reversed. N.B., *Sorex* coded for presence as the first premolar is the first of the antemolars to be lost in *Soricolestes*: Lopatin 2006).
3. Third lower incisor, I₃, present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 3, coding reversed. *Uropsilus*, *Urotrichus* and *Dymecodon* coded for presence following Ziegler, 1971).

4. DP¹ present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 4, coding reversed).
 5. DP₁ present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 5, coding reversed).
 6. P² present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 6, coding reversed).
 7. P₂ present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 7, coding reversed).
 8. P³ with two or more roots (0); single-rooted (1); absent (2). (Sánchez-Villagra *et al.* 2006, characters 8 and 9).
 9. Relative size (height and width) of I¹ and upper canine: canine larger (0); I¹ larger (1). (Sánchez-Villagra *et al.* 2006, character 10, coding reversed).
 10. P⁴, number of roots: three (0); two (1); one (2). (Sánchez-Villagra *et al.* 2006, character 11, coding reversed).
 11. Upper canine, number of roots: one (0); two (1). (Modified from Sánchez-Villagra *et al.* 2006, character 13. N.B. *Asioryctes* has 2, *Ukhaatherium* has one: Kielan-Jaworowska 1981; Novacek *et al.* 1997. One treated as primitive).
 12. Upper canine: caniniform, without posterior crest (0); caniniform with posterior crest (1); premolariform (2). (Sánchez-Villagra *et al.* 2006, character 15).
- UNORDERED.
13. M² relative height of buccal cusps: subequal or paracone > metacone (0); metacone > paracone (1). (Sánchez-Villagra *et al.* 2006, character 14, coding reversed).
 14. M¹ metacone not expanded distolingually (0); expanded (1). (Sánchez-Villagra *et al.* 2006, character 16).

15. M² paraconule present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 17, coding reversed).
16. M² hypocone: absent (0); present distolingual with talon shelf (1); present mesially positioned with talon shelf (2) (Fig. 1C); mesially positioned without talon shelf (or if not distinguished, position on postprotocingulum) (3) (Fig. 1E). (Sánchez-Villagra *et al.* 2006, character 18, but homology corrected from metaconule to hypocone, following Butler, 1988, and states 2 and 3 added).
17. M¹ mesostyle: absent (0); present single (1); present double, close to each other (2); present double, separated by deep valley (3). (Sánchez-Villagra *et al.* 2006, character 19).
18. M² mesostyle: absent (0); present single (1); present double, close to each other (2); present double, separated by deep valley (3). (Sánchez-Villagra *et al.* 2006, character 20).
19. M² postmetacrista and preparacrista subequal (0); postmetacrista longer (1).
(Sánchez-Villagra *et al.* 2006, character 21, coding reversed. Both Sánchez-Villagra *et al.* 2006 and Schwermann and Thompson 2015 have used metacrista and paracrista respectively for these crests).
20. Anterior accessory cuspid of M₂₋₃ (Hutchison 1968, fig. 6): absent (0); present (1).
(Modified from Sánchez-Villagra *et al.* 2006, character 22).
21. Lower molar precingulid: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 23, coding reversed. N.B., soricids coded for presence contra Sánchez-Villagra *et al.* 2006: pers. obs.).
22. Relative heights of M₁ entoconid and metaconid: metaconid > entoconid (0); subequal (1). (Sánchez-Villagra *et al.* 2006, character 24).

23. M₁₋₂ talonid notch: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 25, coding reversed).
24. Position of attachment of M₂ cristid obliqua to back of trigonid: lingual (0); central (1) (PRIMITIVE); buccal (2). (Modified from Sánchez-Villagra *et al.* 2006, character 26).
25. M₁₋₂ talonid: with central hypoconulid on postcristid (0); nyctalodont (1); myotodont (2).
26. Upper premolar row: without gaps (0); with gaps (1). (Sánchez-Villagra *et al.* 2006, character 28. N.B. soricids coded for without).
27. Lower premolar row: without gaps (0); with gaps (1). (Sánchez-Villagra *et al.* 2006, character 42. N.B. soricids coded for without).
28. Contact between I² and I¹: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 29, coding reversed).
29. Upper canine: taller than I¹ (0); subequal to I¹ (1); shorter than I¹ (2). (Sánchez-Villagra *et al.* 2006, character 30, coding reversed).
30. Upper canine length: ≤ width (0); > width (1). (Sánchez-Villagra *et al.* 2006, character 31).
31. Height of P⁴: < upper canine (0); = upper canine (1); > upper canine (2). (Motokawa 2004, character 26, coding reversed).
32. P⁴ protocone large, mesiolingual of paracone (0); small to insignificant, lingual to distolingual of paracone (1). (Replaces Sánchez-Villagra *et al.* 2006, character 33, to which it adds data).
33. P⁴ parastyle: obvious (0); inconspicuous (1). (Sánchez-Villagra *et al.* 2006, character 34).

34. M² length: c.= M¹ length (0); < M¹ length (1). (Sánchez-Villagra *et al.* 2006, character 35).
35. Length of M³: more than half M¹ (0); less than half (1). (Sánchez-Villagra *et al.* 2006, character 36).
36. Crown area of M³: = or > P⁴ (0); < P⁴ (1). (Sánchez-Villagra *et al.* 2006, character 37).
37. DP⁴/₄: functional (0); non-functional (1). (Sánchez-Villagra *et al.* 2006, character 38).
38. Posterior cingulum cusp of I₂: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 39, coding reversed).
39. P₄ paraconid: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 40).
40. P₄ talonid: absent (0); unbasined with hypoconulid (1) (PRIMITIVE); basined with hypoconid and hypoconulid (2). (Modified from Sánchez-Villagra *et al.* 2006, character 41).
41. P₄ metaconid: present (0); absent (1). N.B. Asioryctitheres lack a P₄ metaconid, but its presence is widespread in other primitive eutherians, so presence is treated as primitive here.
42. M¹ preparacrista: present (0); absent (1).
43. Length of M₁ c.= P₄ (0); longer but less than twice as long as P₄ (1); more than twice as long as P₄ (2). (Sánchez-Villagra *et al.* 2006, character 43).
44. Length of M₂: < M₁ (0); M₁ and M₂ subequal (1) (PRIMITIVE); > M₁ (2). (Sánchez-Villagra *et al.* 2006, character 44).
45. Length of M₃: > or subequal to M₁ (0); < M₁ (1). (Sánchez-Villagra *et al.* 2006, character 45, coding changed).
46. M₂ metastylid: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 46).

47. M₂ talonid width: < trigonid (0); subequal to trigonid (1). (Sánchez-Villagra *et al.* 2006, character 47, coding reversed).
48. M₁ crown height, unworn to lightly worn: height of protoconid as percentage of tooth length: >90% (0); <90% (1). (Sánchez-Villagra *et al.* 2006, character 70, related crown height to dentary height. Here, both measurements are from the tooth, reducing the influence of other variables).

Cranium

49. Anterior nasal tip in lateral view: reaches level of incisors (0); level of canines (1); posterior to the posterior margin of canines (2). (Sánchez-Villagra *et al.* 2006, character 48).
50. Anterior extremity of incisive foramen: reaches level of I³ or more posterior (0); reaches level of I² (1); anterior to the anterior margin of the I² (2). (Sánchez-Villagra *et al.* 2006, character 49, polarity reversed). N.B. Not known in Asioryctitheria or other primitive eutherians; polarity taken from *Leptictis* (Novacek 1986).
51. Incisive foramina: small, anteroposterior length shorter than length of M² (0); large, ≥ length of M²⁻³ (1). (Sánchez-Villagra *et al.* 2006, character 63). N.B. Not known in Asioryctitheria or other primitive eutherians; polarity taken from *Leptictis* (Novacek 1986).
52. Anterior extremity of anterior/major palatine foramina reaches: level of M² (0); level of M¹ (1); level of P⁴ (2). (Sánchez-Villagra *et al.* 2006, character 50, coding reversed).
53. Position of posterior border of infraorbital foramen relative to upper molar row: anterior to or at border of M¹ and M² (0); above M² or more posterior (1). (Modified from Sánchez-Villagra *et al.* 2006, character 68).

54. Posterior margin of anterior root of zygomatic arch in ventral view extends: to M³ (0); to M² (1). (Sánchez-Villagra *et al.* 2006, character 51; polarity reversed).
55. Zygomatic plate: dorsoventrally deep (0); shallow (1). (Motokawa 2004, character 6, fig. 2, coding reversed).
56. In dorsal view, location of contact of zygomatic arch with braincase: medial to or at midpoint of anterior margin of braincase (0); at lateral portion of anterior margin of braincase (1); absent (2). (Modified from Sánchez-Villagra *et al.* 2006, character 55, coding reversed). Polarity based on ingroup commonality. UNORDERED.
57. Posterior margin of the infraorbital foramen: extends to M¹ level or more anterior (0); extends to M² level (1); extends to M³ level or more posterior (2). (Reworded and modified from Sánchez-Villagra *et al.* 2006, character 56; Motokawa 2004, character 12).
58. Zygomatic arch complete (0); broken (1). (Sánchez-Villagra *et al.* 2006, character 52).
59. Position of lacrymal foramen: posterior to infraorbital foramen (0); just dorsal or dorsal at the level of the middle portion of infraorbital canal (1); dorsal, just anterior to anterior border of infraorbital canal (2). (Sánchez-Villagra *et al.* 2006, character 62).
60. Foramen "I" in maxilla or premaxillary-maxillary suture: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 64). Polarity based on ingroup commonality.
61. Anterior projection of mastoid: well-developed, projecting laterally (0); weak to absent (1). (Sánchez-Villagra *et al.* 2006, character 58).
62. Anterior process of "mastoid process": below root of zygomatic arch (0); in line with root (1); above root of zygomatic arch (2). (Sánchez-Villagra *et al.* 2006, character 67, coding reversed).

63. Position of posterior extremity of auditory bulla in ventral view: anterior to the anterior process of the “mastoid process” (0); in a similar position (1) PRIMITIVE; posterior (2). (Sánchez-Villagra *et al.* 2006, character 57).
64. Maximal/minimal diameter of fenestra ovalis: <2.5 (0); >2.5 (1). (Sánchez-Villagra *et al.* 2006, character 71).
65. Stapes footplate: not bullate (0); bullate (1). (Sánchez-Villagra *et al.* 2006, character 72). Polarity based on ingroup commonality.
66. Bony canal surrounding stapedia artery traversing the stapedia foramen: absent (0); canal partially or totally ossified (1). (Sánchez-Villagra *et al.* 2006, character 73). Polarity based on ingroup commonality.
67. Number of mental foramina: three or more (0); two (1); one (2). (Sánchez-Villagra *et al.* 2006, character 65, coding reversed).
68. Posterior mental foramen between P₃ and P₄ (0); between P₄ and M₁ (1); below M₁ (2).
69. Posterior tip of the angular process of the dentary: anterior to condyle (0); approximately level with the condyle (1); posterior to the condyle (2). (Sánchez-Villagra *et al.* 2006, character 60).
70. Dentary angular process: plate-like (0); rod-like (1). (Modified from Sánchez-Villagra *et al.* 2006, character 66; coding changed for *Condylura*, where it is narrow but still plate-like, not rod-like).
71. Position of mandibular condyle: between angular process and coronoid tip, but nearer angular process (0); at midpoint between upper sigmoid notch and coronoid tip or nearer coronoid tip (1). (Modified from Sánchez-Villagra *et al.* 2006, characters 59 and 61).

Postcranial, axial

72. Axis and C3: not ankylosed (0); ankylosed (1). (Sánchez-Villagra *et al.* 2006, character 85).
73. Axis neural spine: cranio-caudally orientated keel (0); simple knob (1). (Sánchez-Villagra *et al.* 2006, character 86, coding reversed).
74. C6 transverse process posterior extension: does not reach C7-T1 border (0); reaches or surpasses this border (1). (Sánchez-Villagra *et al.* 2006, character 87).
75. Number of caudal vertebrae: 20 or more (0); <20, >14 (1); 14 or fewer (2). (Sánchez-Villagra *et al.* 2006, character 88, coding reversed). Polarity based on *Eomaia* (Ji *et al.* 2002).
76. Sternum ventral surface: no distinct ridge (0); distinct ridge, but no keel (1); prominent keel (2). (Sánchez-Villagra *et al.* 2006, character 83). Polarity based on ingroup commonality.
77. Sternum, proportions of manubrium: length/width <1.5 (0); 1.5-3 (1); 3-4.5 (2); >4.5 (3). (Sánchez-Villagra *et al.* 2006, character 84). Polarity based on ingroup commonality.
78. Dorsal surface of manubrium: smooth (0); contains a well-defined trough (1); features a ridge, sometimes perforated by a foramen (2). (Schwermann and Thompson 2015, character 158). UNORDERED

Postcranial, appendicular, forelimb

79. Clavicle: elongate, in some cases with strong processes directed medio-ventrally (0); semirectangular, stout (1); quadratic (length c.= width) (2). (Sánchez-Villagra *et al.* 2006, character 74). Polarity based on commonality in modern placentals.

80. Clavicle, “foramen for vein”: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 75). Polarity based on commonality in modern placentals.
81. Clavicle, articulations: with scapula (0); with scapula and humerus (1); with just humerus (2). (Sánchez-Villagra *et al.* 2006, character 76). Polarity based on commonality in modern placentals.
82. Tetrahedral heterotopic bone wedged between ventromedial spine of the clavicle and anterior basilateral portion of the manubrium: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 77). Polarity based on ingroup commonality.
83. Scapula, suprascapular canal through base of acromion: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 78). Polarity based on ingroup commonality.
84. Scapula, infraspinous fossa: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 79, coding reversed).
85. Scapula, marked teres fossa: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 80).
86. Scapula metacromion: absent (0); present < one third the length of the spine (1); present \geq one third the length of the spine (2). (Sánchez-Villagra *et al.* 2006, character 81).
87. Scapula, coracoid process: conspicuous (0); inconspicuous (1). (Sánchez-Villagra *et al.* 2006, character 82, coding reversed). Polarity based on *Eomaia* (Ji *et al.* 2002).
88. Deltoid process of humerus: absent (0); present as flange distal to the greater tuberosity (1); present as elongate hook on lateral edge of greater tuberosity (2). (Sánchez-Villagra *et al.* 2006, character 89, states corrected by Schwermann and Thompson 2015).
89. Position of humeral head: on posterior to posteromedial side of proximal end (0); lateral edge to centre of head in line with lateral edge of shaft (1); medial edge of

- head in line with lateral edge of shaft (2); entire head lateral to lateral edge of shaft (3). (Sánchez-Villagra *et al.* 2006, character 90, where state 3 was not scored. Some states have been recoded).
90. Orientation of humeral head: long axis of head parallel or subparallel to shaft long axis (0); long axis of head at oblique angle to shaft long axis (1). (Sánchez-Villagra *et al.* 2006, character 91).
91. Minimum width of humerus: approximately 1/9-1/10th of maximum length of humerus (0); approximately 1/7th (1); approximately 1/4-1/5th (2); approximately 1/3rd or less (3). (Sánchez-Villagra *et al.* 2006, character 92).
92. Distal end of pectoral crest of humerus: does not form pronounced and distinct process (0); forms pronounced and distinct process orientated proximo-medially (1); small but prominent process protruding at right angles to shaft (2). (Sánchez-Villagra *et al.* 2006, character 93, modified Schwermann and Thompson 2015). UNORDERED
93. Proximity of pectoral crest to lesser tuberosity: clear gap with low proximal end of pectoral process (0); narrow gap or fused to form a bicipital tunnel (1). (Sánchez-Villagra *et al.* 2006, character 94).
94. Floor of bicipital groove: straight and parallel to long axis of humerus (0); displaced medially by pectoral crest near proximal end of humerus (1). (Sánchez-Villagra *et al.* 2006, character 95).
95. Open portion of proximal half of bicipital groove: visible in anterior view (0); visible in posterior view (1). (Modified from Sánchez-Villagra *et al.* 2006, character 96, where a state 2, “not visible”, was not scored).
96. Pit for m. flexor digitorum profundus: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 97).

97. Medial edge of humeral trochlea: sharp, ventrally projecting ridge (0); straight or low ridge (1). (Sánchez-Villagra *et al.* 2006, character 98).
98. Lateral epicondyle: present as rounded protuberance (0); forms laterally extended flange (1); has proximally directed hook (2); has spine-like proximally pointed hook (3). (Sánchez-Villagra *et al.* 2006, character 99).
99. Brachial fossa: small pit (0); cavernous excavation underlying greater tuberosity (1). (Sánchez-Villagra *et al.* 2006, character 100).
100. Crest between greater tuberosity and distal end of pectoral ridge: present (0); absent (1). (Sánchez-Villagra *et al.* 2006, character 101).
101. Trough between head of humerus and greater tuberosity: very shallow to absent (0); deep groove (1). (Sánchez-Villagra *et al.* 2006, character 102).
102. Lesser tuberosity in posterior view: lower than proximal edge of head (0); level with proximal edge of head (1) higher than proximal edge of head (2). (Sánchez-Villagra *et al.* 2006, character 103, modified Schwermann and Thompson 2015).
103. Humeral head round (0); elliptical (1). (Sánchez-Villagra *et al.* 2006, character 104).
104. Scalopine ridge, running between the medial root of the humeral head and the distal margin of the lesser tuberosity: absent or weak (0); present as a distinct ridge or shelf (1). (Schwermann and Thompson 2015, character 171).
105. Medial epicondyle, proximally elongate flange or process: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 105).
106. Greatest length of greater tuberosity and deltoid process: relatively short, c. $<1/4$ length of humerus (0); longer (1). (Sánchez-Villagra *et al.* 2006, character 106).
107. Pectoral crest: single straight process parallel to humerus long axis (0); forms single curved process (1); long axis of humerus and pectoral crest have

- perpendicular orientation (c.90 degrees) (2). (Sánchez-Villagra *et al.* 2006, character 107).
108. Clavicular facet: absent (0); present (1). (Modified from Sánchez-Villagra *et al.* 2006 and Schwermann and Thompson, 2015, character 108, as few taxa have been coded on shape).
109. Lateral side of capitulum: not noticeably elongate (0); laterally elongate, so that capitulum has fusiform shape (1). (Sánchez-Villagra *et al.* 2006, character 109).
110. Teres tubercle of humerus: absent (0); a weak muscle scar (1); a distinct proximodistally short process (2); a distinct proximodistally elongate process (3). (combined from Schwermann and Thompson, 2015, characters 172, 173).
111. Length of olecranon process of ulna: c.= length of semilunar notch (0); longer (1). (Modified from Schwermann and Thompson, 2015, character 167 to allow incomplete *Eotalpa* ulna to be coded).
112. Ulna, radial facet: flat to concave (0); convex, steep on lateral face (1). (Includes radial capitular process: Schwermann and Thompson, 2015, character 170).
113. Ulna radial facet: confluent distally with humeral facet (0); separated distally by notch (1).
114. Ulna, proximal olecranon crest: absent (0); incipient, lateral process at level of anconal process (1) (Figs 4B, D, 5G); well-developed, but strongly oblique (2) (Fig. 5C, H); well-developed and nearly transverse (3) (Fig. 5D, E, I-J). (Modified from Schwermann and Thompson, 2015, character 166).
115. Anterior tubercle of olecranon: absent (0) (Fig. 5A); present, strong, halfway along olecranon (1) (Fig. 5B); present, strong, at proximal end of olecranon (2) (Fig. 5C); present, weak towards proximomedial end of medial olecranon crest, where it meets the edge of the triceps area of insertion (3) (Fig. 5D); subsumed where the medial

crest meets the triceps area of insertion at the medial extremity of the proximal olecranon crest (4) (Fig. 5E).

116. Ulna, anconal process: weak (0); strong (1).

117. Ulna coronoid process: weak (0); strong (1).

118. Abductor fossa and posterior crest of ulna: fossa narrow and very shallow, and crest a weak ridge (0); fossa deep, forming thin plate of bone and laterally curved forming a pronounced posterior crest (1). (Schwermann and Thompson 2015, character 168, where *Uropsilus* was coded '1', despite having a very narrow fossa as noted by Hutchison, 1968: 15, fig. 4. Nevertheless, the depth in *Uropsilus* is greater than in soricids and appears to begin a trend towards ever broader and deeper fossae: Hutchison, 1968, fig. 13).

119. Terminal process of the distal ulna (sensu Hutchinson 1968), defined as an elongate posteriorly projecting process: absent (0); present (1). (Schwermann and Thompson 2015, character 169).

120. Prepollex: absent (0); present as a knob (1); present, elongate, extending all along the scaphoid, but not reaching metacarpal I (2); present, extending to proximal portion of metacarpal I or beyond (3). (Sánchez-Villagra *et al.* 2006, character 110). Polarity based on commonality in modern placentals.

121. Scaphoid and lunar: not co-ossified (0); co-ossified, suture visible (1); co-ossified, suture not visible (2). (Sánchez-Villagra *et al.* 2006, character 111).

122. Cuneiform, ulno-palmar extension originating from distal portion: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 112). Polarity based on commonality in modern placentals.

123. Small sesamoid lateral to cuneiform: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 113). Polarity based on ingroup commonality.

124. Trapezium distinct distal arms: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 114). Polarity based on ingroup commonality.
125. Centrale: separate (0); absent/co-ossified (1). (Sánchez-Villagra *et al.* 2006, character 115, coding reversed).
126. Pisiform: simple (0); forms a plate larger in area than the cuneiform, extending palmar to the cuneiform, unciform and ulna (1). (Sánchez-Villagra *et al.* 2006, character 116). Polarity based on ingroup commonality.
127. Proximal radial process of metacarpal I: absent (0); present (1). (Sánchez-Villagra and Menke 2005).
128. Length/width ratio of metacarpal IV: X6 (0); X4 (1); X2.5 (2); approximately as broad as long (3). (Partial overlap with Schwermann and Thompson 2015, character 174, but defined to be directly relevant to *Eotalpa*). Polarity based on *Eomaia* (Ji *et al.* 2002).
129. Ungual phalanges at least on fore foot: laterally compressed (0); relatively dorsoventrally compressed (1).

Postcranial, appendicular, hind limb

130. Fusion of acetabular area to vertebrae: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 117). Polarity based on ingroup commonality.
131. Fusion of posterior horizontal branch of ischium to vertebrae: absent (0); transverse processes expanded but not fused to ischium (1); fused (2). (Sánchez-Villagra *et al.* 2006, character 118). Polarity based on commonality in modern placentals.
132. Pubic approach: absent (0); pubes approach one another beneath acetabulum (1); pseudosymphysis formed (2). (Sánchez-Villagra *et al.* 2006, character 119, modified

- Schwermann and Thompson 2015). Polarity based on commonality in modern placentals.
133. Pubic symphysis in the shape of a narrow bridge: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 120). Polarity based on ingroup commonality.
134. Femur, greater trochanter height: level with or below head (0); higher than head (1). (Sánchez-Villagra *et al.* 2006, character 121).
135. Third trochanter: absent (0); present, distal of lesser trochanter a small short flange (1); present, level with lesser trochanter, a small short flange (2); present, level with lesser trochanter, a short but broad and robust hooked flange (3).
(Modified from Sánchez-Villagra *et al.* 2006, character 122 and Schwermann and Thompson 2015, character 176).
136. Tibia and fibula: separate or with syndesmosis (0); synostosed (1).
137. Tibial distal bridge: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 123).
138. Tibial falciform process: absent (0); proximodistal blade (1); actual laterally projecting falciform process (2). (Sánchez-Villagra *et al.* 2006, character 124).
139. Fibular lateral process: absent (0); simple lateral process (1); process with proximal head (2); process with proximal and distal heads (3). (Sánchez-Villagra *et al.* 2006, character 125).
140. Fibular posterior process: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 126).
141. Astragalus, process on lateral side of body: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 127).
142. Astragalar head width: narrower than body (0); as wide as body or wider (1).
(Sánchez-Villagra *et al.* 2006, character 128).

143. Astragalar head, lateral side height relative to medial side: equal (0); lateral side higher (1). (Sánchez-Villagra *et al.* 2006, character 129).
144. Astragalar transverse ridge or groove proximal to trochlea: absent (0); ridge or groove (1). (Modified from Sánchez-Villagra *et al.* 2006, character 130. State 1, which is an autapomorphy of *Scalopus*, is combined with state 2).
145. Astragalar proximoventral groove for the flexor digitorum fibularis tendon: shallow groove (0); deep groove or canal (1). (Sánchez-Villagra *et al.* 2006, character 131).
146. Astragalar body proportions: mediolaterally wider (0); equidimensional (1); mediolaterally narrower (2). (Sánchez-Villagra *et al.* 2006, character 132).
147. Astragalar medial trochlear ridge orientation: proximodistal (0); proximally more lateral (1). (Sánchez-Villagra *et al.* 2006, character 133).
148. Distal end of astragalar lateral trochlear ridge ends on the distal end of the body (0); body is longer (1). (Sánchez-Villagra *et al.* 2006, character 134, but coded in reverse).
149. Astragalar medial plantar tuberosity: does not protrude medially beyond medial trochlear ridge (0); protrudes medially (1). (Sánchez-Villagra *et al.* 2006, character 135).
150. Astragalar neck angle with trochlea: large angle (0); small angle (1). (Sánchez-Villagra *et al.* 2006, character 136, coding reversed).
151. Astragalar proximoventral groove does not protrude proximally in dorsal view (0); protrudes proximally (1). (Sánchez-Villagra *et al.* 2006, character 137).
152. Calcaneum, sustentacular facet dimensions: mediolaterally larger (0); equidimensional, round to square (1); proximodistally longer (2). (Sánchez-Villagra *et al.* 2006, character 138).

153. Calcaneum, peroneal process distal extent: proximal of or level with cuboid facet (0); protrudes distally (1). (Sánchez-Villagra *et al.* 2006, character 139).
154. Calcaneum, peroneal process lateral extent: protrudes laterally (0); does not protrude laterally (1). (Sánchez-Villagra *et al.* 2006, character 140, polarity reversed).
155. Peroneal process position: lateral to calcaneocuboid facet (0); dorsolateral to calcaneocuboid facet (1). (Sánchez-Villagra *et al.* 2006, character 141).
156. Calcaneal cuboid facet, major axis: mediolaterally larger (0); equilateral axes (1); dorsoventrally larger (2); dorsoventrally much larger (3). (Sánchez-Villagra *et al.* 2006, character 142).
157. Ectal facet: without concave proximal extension (0); with concave proximal extension (1). (Sánchez-Villagra *et al.* 2006, character 143).
158. Peroneal process and sustentaculum proximodistal lengths: equal or peroneal process longer (0); peroneal process shorter (1). (Sánchez-Villagra *et al.* 2006, character 144, polarity reversed).
159. Ectocuneiform medial canal: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 145).
160. Navicular: tibial tuber weak to absent (0); short (1); long (2). (reworded from Sánchez-Villagra *et al.* 2006, character 146). N.B. primitive state is based on *Eomaia* (Ji *et al.* 2002), as the navicular is not known in Asioryctitheria.
161. Navicular ventral articular area: absent (0); ventral facet smaller than that on tuber (1); ventral and tuber facets subequal (2). (Sánchez-Villagra *et al.* 2006, character 147).
162. Navicular shape in dorsal view: mediolaterally wider (0); proximodistally longer (1). (Sánchez-Villagra *et al.* 2006, character 148).

163. Cuboid, medial proximal process: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 149).
164. Cuboid ventrolateral tunnel: absent (0); present (1). (Sánchez-Villagra *et al.* 2006, character 150).
165. Cuboid proximal surface proximodistal location relative to that of the navicular: cuboid surface more distal (0); equal (1). (Sánchez-Villagra *et al.* 2006, character 151, polarity reversed).
166. Prehallux: absent or not in contact with entocuneiform and navicular (0); in contact (1). (Sánchez-Villagra *et al.* 2006, character 152).
167. Metatarsal I: with symmetrically opposite proximal and distal articulations (0); distal articulation twisted laterally (1).
168. Length of metatarsal III relative to calcaneum: much longer, at least 1.31 times longer (0); between 1.16 and 1.01 times longer (1); shorter (2). (Sánchez-Villagra *et al.* 2006, character 153).
169. Metatarsal IV distal extent relative to M/T III: about equal or M/T IV shorter (0); M/T IV extends beyond M/T III (1). (Sánchez-Villagra *et al.* 2006, character 154).
170. Metatarsal V proximal lateral process: absent (0); terminal (1); subterminal (2).
UNORDERED.
171. Metatarsal V cuboid facet: present, large (0); present, small (1); absent (2).

Schwermann and Thompson's (2015) character list

Note: An asterisk "*" indicates the character is additive or ordered. Some citations include "char. XX" to specify the character number used by the original authors to refer to the same or similar feature.

Dental characters

1. First lower incisor i1: 0 = absent; 1 = present.
2. Third upper incisor I3: 0 = absent; 1 = present.
3. Third lower incisor i3: 0 = absent; 1 = present.
4. Upper dP1: 0 = absent; 1 = present.
5. Lower dp1: 0 = absent; 1 = present.
6. Upper P2: 0 = absent; 1 = present.
7. Lower p2: 0 = absent; 1 = present.
8. Upper P3: 0 = absent; 1 = present.
9. Upper P3, number of roots: 0 = single-rooted; 1 = two or more roots.
10. Relative size (height and width) of first upper incisor and canine: 0 = first upper incisor larger; 1 = canine larger.
11. Upper P4, number of roots*: 0 = 1 root; 1 = 2 roots; 2 = 3 roots. The following taxa were coded following Hutchison (1968, p. 20, table 2): *Scaptonyx*, *Talpa europaea*, *Scaptochirus*, *Urotrichus*, *Neurotrichus*, *Scapanulus*, *Parascalops*, *Scalopus*, *Scapanus*, *Condylura*.
12. Upper canine C: 0 = absent; 1 = present.
13. Upper canine C, number of roots: 0 = 1 root; 1 = 2 roots.
14. Second upper molar M2, relative height of buccal cusps: 0 = metacone > paracone; 1 = subequal or paracone > metacone.
15. Upper canine caniniform, with single posterior crest: 0 = posterior crest absent; 1 = posterior crest present.
16. Upper first molar M1, metacone is expanded posterolingually and approaches the position and function of a hypocone (Van Valen, 1967): 0 = not; 1 = yes.

17. Upper M2, distinct paraconule: 0 = absent; 1 = present
18. Upper M2, distinct metaconule: 0 = absent; 1 = present.
19. First upper molar M1, mesostyle: 0 = absent; 1 = just one mesostyle visible; 2 = two mesostyles close to each other; 3 = two mesostyles separated by deep valley.
20. Second upper molar M2, mesostyle: 0 = absent; 1 = just one mesostyle visible; 2 = two mesostyles close to each other; 3 = two mesostyles separated by deep valley.
21. Second upper molar M2, relative length of metacrista and paracrista: 0 = metacrista longer than paracrista; 1 = subequal.
22. "Anterior accessory cuspid (acc)" (Fig. 9; Hutchison, 1968, fig. 6) or in other words, small mesial (anterior) discrete shelf (additional cuspule) to paraconid in lower m2: 0 = absent; 1 = present.
23. Distinctive anterior cingulum in lower molars m1-m2: 0 = absent; 1 = present.
24. Relative height of entoconid/metaconid in m1: 0 = metaconid > entoconid; 1 = subequal.
25. Talonid notch in m1/m2: 0 absent; 1 = present.
26. Cristid obliqua in m2: 0 = separated from posterior wall of trigonid by a notch; 1 = connected to posterior wall of the trigonid.
27. Teeth red-tipped when unworn: 0 = no; 1 = yes.
28. Premolar row, when more than one upper premolar present (modified from Motokawa, 2004; char. 19): 0 = crowded; 1 = gapped.
29. Contact of second upper incisor with first incisor (based on Motokawa, 2004, char. 22): 0 = absent; 1 = present.
30. Height of the upper canine in contrast to that of the first incisor (modified from Motokawa, 2004, char. 24)*: 0 = UC shorter than first incisor; 1 = subequal; 2 = taller.

31. Crown length versus width of the upper canine (based on Motokawa, 2004, char. 25): 0 = subequal; 1 = crown length greater.
32. Crown height of the fourth upper premolar versus that of the upper canine (based on Motokawa, 2004, char. 26)*: 0 = fourth upper molar shorter; 1 = subequal; 2 = fourth upper molar taller.
33. Crown length versus width of the fourth upper premolar (based on Motokawa, 2004, char. 27): 0 = length greater or subequal; 1 = length smaller than width.
34. The parastyle of the fourth upper premolar (based on Motokawa, 2004, char. 28): 0 = obvious; 1 = inconspicuous.
35. The crown length of the second upper molar versus that of the first molar (based on Motokawa, 2004, char. 31): 0 = subequal; 1 = smaller in the second upper molar.
36. Crown length of third upper molar versus that of the first molar (based on Motokawa, 2004, char. 32): 0 = crown length of the third upper molar more than half than that of the first molar; 1 = less than half.
37. Crown area of third upper molar versus that of the fourth premolar (based on Motokawa, 2004, char. 33): 0 = area of third upper molar subequal or larger; 1 = area of third upper molar smaller.
38. The metacingulum of the second upper molar (based on Motokawa, 2004, char. 38): 0 = present; 1 = absent.
39. Posterior cingulum cusp of the second lower incisor (based on Motokawa, 2004, char. 41): 0 = present; 1 = absent.
40. Anterior cingulum cusp of the fourth lower premolar (based on Motokawa, 2004, char. 42): 0 = present; 1 = absent.
41. Posterior cingulum cusp of the fourth lower premolar (based on Motokawa, 2004, char. 43): 0 = present; 1 = absent.

42. Lower premolar teeth (modified from Motokawa, 2004, char. 44): 0 = crowded; 1 = gapped.
43. Crown length of the first lower molar versus, that of the fourth premolar (based on Motokawa, 2004, char. 45)*: 0 = subequal; 1 = greater in first lower molar; 2 = much greater (more than twofold).
44. Crown length of second lower molar versus that of first molar (based on Motokawa, 2004, char. 47)*: 0 = smaller in second lower molar; 1 = subequal; 2 = greater in second lower molar.
45. Crown length of third lower molar versus that of first molar (based on Motokawa, 2004, char. 48)*: 0 = much smaller and minute in third lower molar; 1 = subequal or smaller third lower molar; 2 = greater third lower molar.
46. Metastylid of second lower molar (based on Motokawa, 2004, char. 49; see also Hutchison, 1968, table 2, p. 20, fig. 6): 0 = absent; 1 = present.
47. Trigonid and talonid width of second lower molar: 0 = trigonid and talonid width subequal; 1 = trigonid width greater than talonid width.

Cranial characters

48. Anterior nasal tip in lateral view (based on Motokawa, 2004, char. 1)*: 0 = reaches the level of the incisors; 1 = the level of the canines; 2 = posterior to the posterior margin of the canines. Coding for *Scaptochirus* is 0 (contra Motokawa, 2004).
49. The anterior extremity of the incisive foramen (based on Motokawa, 2004, char. 2)*: 0 = anterior to the anterior margin of the second incisor; 1 = the level of the second incisor; 2 = reaches the level of the third incisor or posterior.

50. The anterior extremity of the palatine foramen (modified from Motokawa, 2004, char. 3)*: 0 = reaches level of P4; 1 = reaches level of first molar; 2 = reaches level of second molar.
51. Posterior margin of the anterior root of the zygomatic arch in ventral view ("anterior margin of the orbital region" of Motokawa, 2004, char. 5; wording modified same coding): 0 = extends to the second molar; 1 = extends to the third molar.
52. Zygomatic arch: 0 = absent; 1 = present.
53. Zygomatic arch (modified from Motokawa, 2004, char. 6): 0 = shallow; 1 = deep (its height exceeds half the cranial height at a given position).
54. Lateral view of the zygomatic arch (modified from Motokawa, 2004, char. 8): 0 = curved upwards; 1 = straight or slightly curved downwards.
55. In dorsal view, location of contact of zygomatic arch with braincase (based on Motokawa, 2004, char. 10): 0 = lateral portion of the anterior margin of the braincase; 1 = medial to or at the middle point of the anterior margin of the braincase.
56. The anterior face of the zygomatic arch (modified from Motokawa, 2004, char. 12)*: 0 = extends to the first molar level; 1 = extends to second molar; 2 = extends to the third molar level; 3 = positioned posterior to the posterior margin or the third molar.
57. Position of posterior extremity of the auditory bulla in ventral view (based on Motokawa, 2004, char. 15)*: 0 = anterior to the anterior process of "mastoid process" (Motokawa, 2004); 1 = in a similar position; 2 = posterior.
58. Anterior projection of mastoid ("mastoid process" sensu Motokawa, 2004) (modified from Motokawa, 2004, char. 17): 0 = well developed, projecting laterally; 1 = weakly developed or absent.

59. Dentary, upper sigmoid notch extension (based on Motokawa, 2004, char. 51): 0 = upwards to the midline, between the uppermost portion of the lower base of the mandible and coronoid tip; 1 = subequal to that level.
60. The posterior tip of the angular process of the dentary (based on Motokawa, 2004, char. 52)*: 0 = anterior to the condyle; 1 = similar; 2 = posterior to the condyle.
61. Position of the mandibular condyle (based on Motokawa, 2004, char. 54)*: 0 = below midline; 1 = midline, between the upper sigmoid notch and the coronoid tip; 2 = upwards towards the coronoid process.
62. Relative position of lacrimal foramen relative to infraorbital foramen: 0 = posterior to infraorbital foramen; 1 = just dorsal or dorsal at the level of the middle portion of infraorbital canal; 2 = dorsal, just anterior to anterior border of infraorbital canal.
63. Foramina incisiva (sensu Koppers, 1990): 0 = small, antero-posterior length shorter than length of M2; 1 = hypertrophied, antero-posterior length equal or longer than added length of two last upper molars.
64. Foramen "I" (Koppers, 1990) in maxillare or in premaxillare-maxillare suture. 0 = absent; 1 = present.
65. Number of mental foramina, buccal side of dentary*: 0 = one; 1 = two; 2 = three or more.
66. Mandibular angular process: 0 = rod-like; 1 = plate; 2 = knob.
67. Anterior process of "mastoid process"*: 0 = above root of zygomatic arch; 1 = in line with root; 2 = below root of zygomatic arch.
68. Relative position of posterior border of infraorbital foramen to upper molar row*: 0 = anterior to or at border M1-M2; 1 = above, somewhere in M2 of border M2-M3; 2 = above, posterior to border M2-M3.

69. Relative position of anterior border (internal side) of zygomatic arch to upper molar row*: 0 = above, anterior to posterior end of M2; 1 = above, between border M2-M3 and posterior end of M3; 2 = above, posterior to M3.
70. Height of M1 crown at buccal side/dentary height in adults without much wear in their teeth: 0 = ratio typically below 1, 1 = ratio above 1.
71. Fenestra ovalis shape: 0 = maximal/minimal diameter less than 2.5; 1 = maximal/minimal diameter more than 2.5
72. Stapes footplate: 0 = not bullate; 1 = bullate (sensu Sánchez-Villagra and Nummela, 2001).
73. Bony canal surrounding stapedia artery traversing the stapedia foramen: 0 = absent; 1 = canal partially or totally ossified.

Postcranial characters: shoulder region

74. Clavicle: 0 = elongated, in some cases with strong processes directed medio-ventrally; 1 = semirectangular, stout; 2 = quadratic (length c. = width).
75. Clavicle, "foramen for vein" (Campbell, 1939, p. 5, figs 11-20): 0 = absent; 1 = present.
76. Clavicle, articulations*: 0 = with scapula; 1 = with scapula and humerus; 2 = with just humerus.
77. Tetrahedral heterotopic bone wedged in between the ventromedial spine of the clavicle and anterior basilateral portion of the manubrium" (Hutchison 1968, p. 21): 0 = absent; 1 = present.
78. Scapula, suprascapular canal through the base of acromium (see Campbell, 1939, figs 27-29): 0 = absent; 1 = present.

79. Scapula, infraspinous fossa (following Campbell, 1939; see also Reed, 1951): 0 = absent; 1 = present.
80. Scapula, marked teres fossa (see Sánchez-Villagra et al. 2006, fig. 5; Campbell, 1939, figs 22-31): 0 = absent; 1 = present.
81. Scapula, metacromium*: 0 = absent; 1 = present, small (length less than 1/3 length of the total spine); 2 = present, large (length equal or more than 1/3 length of the total spine).
82. Scapula, coracoid process (= metacoracoid, Klima, 1987) forms a distinctive process: 0 = does not form conspicuous process; 1 = conspicuous process.
83. Sternum, ventral surface: 0 = absence of distinct ridge; 1 = distinct ridge does not form a keel; 2 = prominent keel.
84. Sternum, proportions of manubrium*: 0 = manubrial length/width less than 1.5; 1 = between 1.5 and 3; 2 = between 3.0 and 4.5; 3 = more than 4.5.

Postcranial characters: vertebral column

85. Axis and C3, relation of neural spines: 0 = not ankylosed; 1 = ankylosed dorsally.
86. Axis, neural spine: 0 = simple knob; 1 = keel with cranio-caudal orientation.
87. C6 transverse process posterior extension (Horovitz and Sánchez-Villagra, 2003, char. 19): 0 = does not reach border C7-T1; 1 = reaches or surpasses border C7-T1.
88. Number of caudal vertebrae*: 0 = equal or less than 14; 1 = more than 14, less than 20; 2 = 20 or more.

Humeral characters

89. "Deltoid process: 0 = absent; 1 = present as flange distal to the greater tuberosity; 2 = present as elongate hook on lateral edge of greater tuberosity.
90. "Position of humeral head: 0 = on posterior to posteromedial side of proximal end; 1 = lateral edge to center of head in line with lateral edge of shaft; 2 = medial edge of head in line with lateral edge of shaft; 3 = entire head lateral to lateral edge of shaft" (Sánchez-Villagra et al., 2004, char. 2).
91. "Orientation of humeral head: 0 = long axis of head parallel or subparallel to long axis of shaft; 1 = long axis of head at oblique angle to long axis of shaft" (Sánchez-Villagra et al., 2004, char. 3).
92. "Minimum width of humerus*: 0 = approximately 1/9-1/10th of the maximum length of humerus; 1 = approximately 1/7th; 2 = approximately 1/4-1/5th; 3 = approximately 1/3rd or less.
93. This character is modified in this study. See sections entitled 'Modified characters' below for details.
94. "Proximity of pectoral crest to lesser tuberosity: 0 = clear gap with a low proximal end of pectoral process; 1 = narrow gap or fused to form a bicipital tunnel.
95. "Floor of bicipital groove: 0 = straight and parallel to long axis of humerus; 1 = displaced medially by pectoral crest near proximal end of humerus" (Sánchez-Villagra et al., 2004, char. 7).
96. "Open portion of proximal half of bicipital groove: 0 = visible in anterior view; 1 = visible in posterior view; 2 = not visible" (Sánchez-Villagra et al., 2004, char. 8).
97. "Pit for M. flexor digitorum profundus: 0 = absent, 1 = present" (Sánchez-Villagra et al., 2004, char. 10).
98. "Medial edge of trochlea: 0 = sharp, ventrally projecting ridge; 1 = straight or low ridge" (Sánchez-Villagra et al., 2004, char. 11).

99. "Lateral epicondyle: 0 = present as rounded protuberance; 1 = distal end forms laterally extended flange; 2 = lateral end has proximally directed hook; 3 = lateral end has spine-like proximally pointed hook" (Sánchez-Villagra et al., 2004, char. 12).
100. "Brachial fossa: 0 = small pit; 1 = cavernous excavation underlying greater tuberosity" (Sánchez-Villagra et al., 2004, char. 13).
101. "Crest between greater tuberosity and distal end of pectoral ridge: 0 = present; 1 = absent" (Sánchez-Villagra et al., 2004, char. 14).
102. "Trough between head of humerus and greater tuberosity: 0 = no groove/very shallow; 1 = deep groove" (Sánchez-Villagra et al., 2004, char. 15).
103. This character is modified in this study. See sections entitled 'Modified characters' below for details.
104. "Head of humerus: 0 = round; 1 = elliptical.
105. "Medial epicondyle builds proximally elongated flange or process: 0 = absent; 1 = present" (Sánchez-Villagra et al., 2004, char. 18).
106. "Greatest length of greater tuberosity and deltoid process: 0 = relatively short, approximately $< \frac{1}{4}$ length of humerus; 1 = relatively long" (Sánchez-Villagra et al., 2004, char. 19).
107. "Pectoral crest: 0 = single straight process parallel to long axis of humerus; 1 = forms single curved process; 2 = long axis of humerus and pectoral crest having a perpendicular orientation (approximately 90°)" (Sánchez-Villagra et al., 2004, char. 20).
108. "Clavicular facet: 0 = absent; 1 = in lateral view wedge-shaped; 2 = rectangular; 3 = sharp ending" (Sánchez-Villagra et al., 2004, char. 26).
109. "Lateral side of capitulum: 0 = not noticeably elongated; 1 = laterally elongated so that capitulum has "football" shape" (Sánchez-Villagra et al., 2004, char. 28).

Hand characters

110. "Prepollex*: 0 = absent; 1 = present, just a knob; 2 = present, elongated, extending all along the scaphoid, but does not reach first metatarsal; 3 = present, extends to proximal portion of first metatarsal or beyond (os falciforme).
111. "Scaphoid and lunate*: 0 = not fused; 1 = fused: suture visible; 2 = fused, suture not visible.
112. "Triquetrum, ulno-palmar expansion originating from distal portion: 0 = absent; 1 = present" (Sánchez-Villagra and Menke, 2005, char. 3).
113. "Small sesamoid lateral to triquetrum: 0 = absent; 1 = present" (Sánchez-Villagra and Menke, 2005, char. 4).
114. "Trapezium shape: 0 = distinctive distal arms absent; 1 = distinctive distal arms present. (Sánchez-Villagra and Menke, 2005, char. 5).
115. "Isolated centrale: 0 = absent; 1 = present. (Sánchez-Villagra and Menke, 2005, char. 6).
116. "Pisiform forms a plate larger in area than the triquetrum and palmar to triquetrum, hamate and ulna: 0 = no; 1 = yes (Sánchez-Villagra and Menke, 2005, char. 7).

Pelvis and sacrum characters

117. Fusion of acetabular area to vertebrae (Leche, 1883): 0 = absent; 1 = present.
118. Fusion of posterior horizontal branch of ischion to vertebrae* (Leche, 1883): 0 = absent; 1 = transverse processes expanded but not fused to ischion; 2 = fused.

119. This character is modified in this study. See sections entitled 'Modified characters' below for details.

120. Pubic symphysis in the shape of a narrow bridge (Leche, 1883): 0 = absent; 1 = present.

Hindlimb characters

121. Greater trochanter height: 0 = level with or below femoral head; 1 = higher than femoral head.

122. Third trochanter position: 0 = more distal than lesser trochanter; 1 = at the same level as lesser trochanter.

123. Tibial distal bridge (see Sánchez-Villagra et al. 2006, fig. 7, modified from Horovitz, 2004, char. 124): 0 = absent; 1 = present.

124. Tibial falciform process (Reed, 1951): 0 = absent; 1 = proximodistal blade; 2 = actual laterally projecting falciform process.

125. Fibular lateral process (Reed, 1951): 0 = absent; 1 = simple lateral process; 2 = process with proximal head; 3 = process with proximal and distal heads.

126. Fibular posterior process (Reed, 1951): 0 = absent; 1 = present.

127. Astragalus, process on lateral side of body: 0 = absent; 1 = present.

128. Astragalar head width (see Sánchez-Villagra et al. 2006, fig. 12): 0 = narrower than body; 1 = as wide as body or wider.

129. Astragalar head, lateral side height relative to medial side: 0 = equal; 1 = lateral side higher.

130. Astragalar transverse ridge or groove posterior to trochlea: 0 = absent; 1 = ridge; 2 = groove.

131. Astragalar posteroventral groove (for the flexor fibularis muscle, also known as flexor digitorum profundus, see Sánchez-Villagra et al. 2006, fig. 12): 0 = shallow groove; 1 = deep groove or canal.
132. Astragalar body shape* (see Sánchez-Villagra et al. 2006, fig. 12): 0 = mediolaterally wider; 1 = equal; 2 = anteroposteriorly longer.
133. Astragalar medial trochlear ridge orientation (see Sánchez-Villagra et al. 2006, fig. 12): 0 = anteroposterior; 1 = posteriorly more lateral.
134. Anterior end of astragalar lateral trochlear ridge (modified from Horovitz, 2004, char. 141; see Sánchez-Villagra et al. 2006, fig. 12): 0 = lateral trochlear ridge ends on the anterior end of the body; 1 = body is longer.
135. Astragalar medial plantar tuberosity (AMPT) protrudes medially beyond medial trochlear ridge (see Sánchez-Villagra et al. 2006, fig. 12): 0 = non-protruding; 1 = protruding.
136. Astragalar neck, angle with trochlea (see Sánchez-Villagra et al. 2006, fig. 12): 0 = small angle; 1 = large angle.
137. Astragalar posteroventral groove protrudes posteriorly in dorsal view: 0 = non-protruding; 1 = protruding.
138. Calcaneum sustentacular facet dimensions* (see Sánchez-Villagra et al. 2006, fig. 13): 0 = mediolaterally larger; 1 = round to square; 2 = proximodistally longer.
139. Calcaneum peroneal process distal extent: 0 = level with facet for cuboid; 1 = protrudes distally.
140. Calcaneum peroneal process lateral extent (see Sánchez-Villagra et al. 2006, fig. 13): 0 = does not protrude laterally; 1 = protrudes laterally.
141. Peroneal process position (see Sánchez-Villagra et al. 2006, fig. 13): 0 = lateral to calcaneocuboid facet; 1 = dorsolateral to calcaneocuboid facet.

142. Calcaneum facet for cuboid, major axis*: 0 = mediolaterally larger; 1 = equal axes; 2 = dorsoventrally larger; 3 = dorsoventrally much larger.
143. Ectal facet concave on tuber calcis: 0 = absent; 1 = present.
144. Peroneal process and sustentaculum proximodistal lengths (see Sánchez-Villagra et al. 2006, fig. 13): 0 = peroneal process shorter; 1 = equal or peroneal longer.
145. Ectocuneiform medial canal: 0 = absent; 1 = present.
146. Navicular facet for astragalus*: 0 = distal area larger; 1 = medial and distal equal; 2 = medial area larger.
147. Navicular ventral articular area size*: 0 = absent; 1 = ventral facet smaller than medial facet; 2 = ventral and medial facets subequal.
148. Navicular shape in dorsal view: 0 = mediolaterally wider; 1 = proximodistally longer.
149. Cuboid medial proximal process (Horovitz, 2004, char. 172): 0 = absent; 1 = present.
150. Cuboid ventrolateral tunnel: 0 = absent; 1 = present.
151. Cuboid proximal surface proximodistal location relative to that of the navicular: 0 = equal; 1 = cuboid surface more distal.
152. Prehallux in contact with entocuneiform and navicular (Sánchez-Villagra and Menke, 2005, fig. 8): 0 = absent; 1 = present.
153. Length of Mt III relative to calcaneum*: 0 = much longer, at least 1.31-fold as long as the calcaneum; 1 = Mt III between 1.16 and 1.01-fold longer; 2 = shorter than calcaneum.
154. Mt IV distal extent relative to Mt III: 0 = about equal; 1 = Mt IV extends beyond Mt III.

Soft tissue characters

155. Number of mammae*: 0 = 3 pairs; 1 = 4 pairs; 2 = 5 pairs.

156. Position of nostrils (see Sánchez-Villagra et al. 2006, fig. 14): 0 = anterior; 1 = lateral; 2 = superior

157. Tail: 0 = scaly; 1 = not scaly.

Modified characters

Three characters from the Sánchez-Villagra et al. (2006) matrix were modified, as detailed below:

93. Distal end of pectoral crest: (0) does not form pronounced and distinct process (1) forms pronounced and distinct process oriented proximomedially (2) a small but prominent process protruding at right angles to the humeral shaft. The distal end of the pectoral crest is generally smooth and flat in moles; however shrew-moles do have a distinct tubercle that sticks out prominently from the shaft at this point. We have added state 2 to account for this prominence, which is distinct from that seen in the Soricidae (see Sánchez-Villagra et al. (2004) for details).

103. Position of the lesser tuberosity relative to the proximal edge of the humeral head and the greater tuberosity: (0) inferior to the humeral head (1) level with the humeral head (2) superior to the humeral head and the greater tuberosity, forming a distinct notch in the proximal edge of the humerus between the greater and lesser tuberosities. We have added state 2 to describe the notch which forms between the

lesser tuberosity and humeral head due to the superior position of the lesser tuberosity in some taxa. Campbell (1939) noted this notch only in the Scalopini, though our observations suggest rather that the lesser tuberosity is elevated in the majority of taxa, excluding the Talpini and Uropsilus.

119. Pseudosymphysis of the pubis: (0) absent (1) pubes approach one another beneath the acetabulum, but do not quite touch (2) a pseudosymphysis is formed. We have redefined character 119 to clarify that the pubic approach referred to by Sánchez-Villagra et al. (2006) is beneath the acetabulum, and in some taxa the pubes contact to form the pseudosymphysis of Reed (1951). In addition to these character changes, we re-coded character 89 to correct the miscoding of Sánchez-Villagra et al. (2006), where state 1 appears as 0, and state 2 as 1 in their matrix. This obviously has no effect on the analysis itself, but is rectified here for clarity and to aid interpretation.

New characters

The nineteen new characters introduced to the Sánchez-Villagra et al. (2006) are detailed below.

158. Form of the dorsal surface of the manubrium: (0) smooth (1) contains a well-defined trough (2) features a ridge, sometimes perforated by a foramen. The dorsal surface of the manubrium varies widely in talpids, with most highly fossorial forms showing signs of the passage of a vein over the bone (Campbell, 1939). Most show a distinct trough in the manubrium, while Campbell noted the presence of a median ridge, permeated by a small foramen, indicating the presence of two blood vessels

rather than one in *Parascalops*. This state was also noted in *Scapanulus* by Campbell (1939). Our own observations confirm this pattern, and recognise a similar ridged condition to a manubrium attributed to *Domninoidea mimicus* in the collections of the AMNH (AMNH 74966).

159. Direction of the posterior end of the dorsal trough or ridge in the manubrium: (0) straight (1) deviates to the right side of the body posteriorly. This is another characteristic of the dorsal manubrium noted by both Campbell (1939) and Hutchison (1968), and used in a cladistics analysis here for the first time. A groove which deviates to the right is seen in the *Talpini*.

160. Form of the scapula spine distal to the acromion: (0) smooth, beginning to taper away (1) a distinct tubercle or thickening of the spine (2) an elongate tubercle process. In most taxa the scapula spine remains thin distal to the humerus. A number of talpids show a thickened tubercle towards the end of the spine, while others have an elongate spine or spindle-like process.

161. Form of the metacromion process of the scapula: (0) a relatively short, deltoid or amorphous projection (1) a more elongate process, often appearing 'spindle-like', with a distal terminal bulge. The Sánchez-Villagra et al. (2006) analysis does account for the length of the metacromion relative to the length of the spine. Due to the length of the spine in many taxa, this does not fully capture the variation in form of the metacromion. A number of taxa have a thin metacromion which is shorter than 1/3 of the spine's length.

162. Form of the clavicular facets: (0) facets are of a similar shape (1) the proximal and distal facets have different forms.

163. Angle of the clavicular facets from anterior view: (0) the facets are at different angles (1) near parallel facets.

164. Form of the ventral surface of the clavicle: (0) smooth, lacking a distinct process, though a notch may separate the proximal facet from the body of the clavicle (1) has a distinct ventral process.

165. Form of the ventral process of the clavicle: (0) the process is elongate and ventrally directed (1) the process is elongate and proximovertrally directed almost forming a closed tunnel on its ventral surface. There is great variation in clavicular form within the Talpidae, and these characters aim to better capture this variation. The facets of the clavicle tend to be small and circular, a flattened more elongate semicircle, or large flat and ovoid. Semi-fossorial taxa tend to exhibit different clavicular facets at either end of the bone, while those ambulatory or highly fossorial forms show similar forms at each articulation. The most highly fossorial moles tend to have large flat and parallel facets on their stout clavicae. The ventral processes of the clavicle are present in a number of groups and show some variation in their orientation. Talpini tend to exhibit a ventrally directed process, while shrew-moles, *Parascalops* and *Scapanulus* have more medially directed processes. There are no distinct processes in *Scapanus* and *Scalopus*, though this appears to be a consequence of the closure of the gap between the body and the ventral process: thus their absence is a product of secondary loss.

166. Form of the olecranon process of the ulna: (0) simple rod-like extension of the ulna, lacking any transverse processes (1) a distinct, transversely curved process (proximal process) is present, producing a broad triceps insertion. The ulna was not an area addressed Sánchez-Villagra et al. (2006) analysis, yet it does show some distinct

specialisations (see Hutchison, 1968) linked to fossoriality. A number of characters have been added here to attempt to trace their evolution, including the presence of a distinct lunate proximal process.

167. Ratio of the length of the olecranon process of the ulna to the length of the shaft:

olecranon/shaft (0) <0.4 (1) >0.4. The states for this character are based on the presence of a break in the distribution of the ratios of all taxa in our sample (see Section 6 for details). No taxa fall between 0.33 and 0.48. This neatly divides none fossorial and semi-fossorial forms from their highly fossorial relatives.

168. Form of the abductor fossa and posterior crest of the ulna: (0) the abductor fossa is narrow and the posterior crest is a weak ridge (1) the abductor fossa is deep, forming a thin plate of bone. It is laterally curved forming a pronounced posterior crest.

169. Terminal process of the distal ulna (sensu Hutchison, 1968) , defined as an elongate posteriorly projecting process on the distal ulna: (0) absent (1) present. The presence of a large, posteriorly projecting terminal process is seen in a number of fossorial talpids, and correlates with the 90° rotation of the manus.

170. Capitular process of the radius: (0) absent, or weak (1) present, a strong process that wraps around the distal end of the capitulum. In many talpids the radius articulates with the lateral surface of the ulna, rather than the anterior edge. Its proximal end develops a long process posteriorly which curves around the capitulum of the humerus, strengthening the elbow joint and limiting its range of movement.

171. Scalopine ridge, running between the medial root of the humeral head and the distal margin of the lesser tuberosity: (0) absent or weak (1) present as a deep ridge. This ridge runs from the distal root of the humeral head to the medial edge of the lesser tuberosity. Many talpids show a scar in this region, but others, notably those in

the Scalopini, show a deep shelf or ridge. This is the Scalopine ridge of Campbell (1939).

172. Teres tubercle: (0) absent (1) present.

173. Form of teres tubercle on the medial surface of the humeral shaft: (0) a weak muscle scar (1) a distinct proximodistally short process (2) a distinct proximodistally elongate process. Teres tubercle is seen in all talpids, but not all lipotyphlans. In non-talpids it tends to form a muscle scar, while most talpids have a proximodistally elongate and robust process. Notably both *Uropsilus* and *Condylura* have relatively short teres tubercles. Another variant, not scored here, is the tubercle of the desmans, which tends to lack the distinct proximal corner seen in other groups. This gives its tubercle a triangular rather than rectangular form.

174. Ratio of the maximum width across the metacarpals to the maximum length of the carpals and metacarpals (width/length): (0) <1 (1) $1 \leq x < 1.5$ (2) $1.5 \leq x < 2$ (3) >2 . [Ordered]. This character describes the extent of the 'spade-like' adaptations of the talpid manus. Though the ratios produced do not cluster as well as those of the olecranon process, the categories used here do represent relatively distinct divisions in manus form (see Section 6 for details). The character is treated as ordered in the analysis due to the continual variation in manus size through the group.

175. Ratio of the width across the acetabulae to the width of the last lumbar centrum - (centrum/acetabulum): (0) ≤ 0.35 (1) > 0.35 . The talpid pelvis is very narrow, with Reed (1951) suggesting that more fossorial forms show a narrower acetabular distance. Our data is less conclusive on this point (see Section 6 for details), with the only distinct break in the data separating the Desmanini, *Uropsilus* and outgroups from the other talpids.

176. Form of the third trochanter of the femur: (0) a small, short flange (1) a short but broad and robust, hooked flange (2) an elongate flange running down the femoral shaft.