List of Selected Characters for the Cladistic Analyses

Dental, cranial, and postcranial characters and character states used in the phylogenetic analysis. Characters followed by an asterisk are considered "ordered". Some characters have been modified (different character state interpretation) from the original works (see Character references). These characters have been labeled by " ’ " or " ‘ " . A score of " ? " is used if information is unavailable due to a lack of material or if the character does not apply to a particular taxon. Tooth areas are calculated as the product of mesiodistal (md) length and buccolingual (bl) breadth.

Lower Teeth:

**Incisors**

1. **i1***. Lower incisor number: 0 = three; 1 = two; 2 = one: I1 present, I2 absent; 3 = lower incisors absent.
2. **i2**. Lower incisor occlusal arrangement: 0 = arcuate battery from lateral perspective (U-shaped arcade); 1 = cusp tips staggered (V-shaped arcade).
3. **i3**. Lower incisor crown spacing: 0 = no spaces; 1 = spaces present between crowns.
4. **i4**. I2-C diastema: 0 = present; 1 = absent.
5. **i5***. I1-2 size (ratio of I1-2 area to M1 area): 0 = very small (≤ 0.69); 1 = moderate sized (≥ 0.70, ≤ 1.07); 2 = large (> 1.07).
6. **i6***. I1:I2 proportions (ratio of I1 area to I2 area): 0 = I1 much smaller than I2 (< 0.65); 1 = I1 smaller than I2 (≥ 0.65, < 0.82); 2 = I1 almost as large as I2 (≥ 0.83, < 1.00); 3 = I1 > I2 (≥ 1.01, < 1.25); 4 = I1 >> I2 (≥ 1.25).
7. **i7***. I1 crown width (spatulate incisors only): 0 = considerably wider (m-d) than root (spatulate); 1 = narrow at apex, wider than root; 2 = "styliform" (crown apex approximately the same width as the cervical margin).
8. **i8**. I2 crown cross-sectional shape (ratio of m-d length to b-l breadth): 0 = rounded oval (≥ 0.64); 1 = mesiodistally compressed (< 0.64).
9. **i9***. Lower incisors crown height (crown heights judged from cementoenamel junction to crown tip on the buccal surface): 0 = low crowned; 1 = moderately high crowned; 2 = high crowned.
10. **i11***. Lower incisor roots: 0 = erect or vertical; 1 = slightly procumbent; 2 = very procumbent.
11. **i12***. Lower incisor crowns: 0 = erect or vertical; 1 = procumbent; 2 = very procumbent.
12. **i14**. I1 crown shape: 0 = spatulate; 1 = lanceolate, pointed.
13. **i15**. I2 heel development (a lingual swelling at the base of crown): 0 = heel absent; 1 = heel present.
14. **i17***. Lower first incisor lingual cingulum: 0 = absent to weak; 1 = strong but incomplete; 2 = strong and complete.
15. **i19***. Relative size of I1 to M1 (based on occlusal areas): 0 = I1 very small (I1 << M1); 1 = moderately enlarged (I1 < or = M1); 2 = grossly enlarged (I1 > M1).

**Canines**

16. **c1***. Female C1 cross-sectional area relative to molar cross sectional area: 0 = very small (C1/M1 < 0.40); 1 = moderate (≥ 0.4, < 0.80); 2 = large (≥ 0.80, ≤ 1.20); very large (≥ 1.20).
17. c2*. C1/1 dimorphism (square root of male C1 area/square root of female C1 area): 0 = low (< 1.07); 1 = moderate (≥ 1.07, < 1.17); 2 = high (≥ 1.17).
18. c3. C1 cross-sectional shape: 0 = rounded oval; 1 = mesiodistally compressed; 2 = buccolingually compressed.
19. c4. C1 lingual crest development: 0 = rounded; 1 = sharp.
20. c5. Canine paracristid (not scored if species has canine incorporated into a tooth comb): 0 = oblique to occlusal plane; 1 = nearly horizontal to occlusal plane; 2 = forms part of cropping mechanism with I1-2.
21. c6. Canine height (females): 0 = low, squat; 1 = narrow, short; 2 = tall, at or above tooth row.
22. ML18*. Lower canine crown: 0 = erect or vertical; 1 = procumbent; 2 = very procumbent.
23. ML19*. Lower canine root: 0 = erect or vertical; 1 = slightly procumbent; 2 = very procumbent.

**Premolars**
24. p1. P1/1: 0 = present; 1 = absent.
25. p2. P2: 0 = present; 1 = absent.
27. p4'. P3 roots: 0 = single; 1 = double.
28. p4''. P4 roots: 0 = single; 1 = double.
29. p5*. Premolar crowding (overlapping of crowns): 0 = no crowding; 1 = slightly crowded; 2 = very crowded—mesial root positioned buccal to distal root.
30. p6*. P3 paraconid: 0 = large; 1 = small; 2 = absent or extremely small.
31. p7*. P4 paraconid: 0 = large; 1 = small; 2 = absent or extremely small.
32. p9''. P4 paraconid position (mesiodistally): 0 = widely spaced from the metaconid; 1 = twinned with metaconid.
33. p11*. P3,4 cristid obliqua: 0 = absent; 1 = weak; 2 = strong.
34. p13. P2 protoconid height and shape: 0 = slender, projects above protoconids of P3-4; 1 = massive, projects above protoconids of P3-4; 2 = not projecting, in line with P3; 3 = extremely short, shorter than P3.
35. p14. P4 metaconid position: 0 = close to protoconid; 1 = widely spaced from protoconid.
36. p15. P3 metaconid size: 0 = absent or trace; 1 = small.
37. p16*. P3 metaconid size: 0 = absent or trace; 1 = small; 2 = large (as big as protoconid).
38. p17*. P4 metaconid size: 0 = absent or trace; 1 = small; 2 = large (as big as protoconid).
40. p19. P3 entoconid and lingual talonid crest: 0 = absent; 1 = lingual talonid crest present but an entoconid does not stand out above it; 2 = entoconid forms a small discrete cusp.
41. p20. P4 entoconid and lingual talonid crest: 0 = absent; 1 = lingual talonid crest present but an entoconid does not stand out above it; 2 = entoconid forms a small discrete cusp.
42. p21. P4 lateral and medial protocristid: 0 = continuous between metaconid and protoconid; 1 = discontinuous between metaconid and protoconid.
43. p22. P4 lateral protocristid orientation: 0 = transversely oriented; 1 = distolingually oriented; 2 = absent.
44. p23. P4 lateral protocristid orientation: 0 = transversely oriented; 1 = distolingually oriented.
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<th>Page</th>
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<tr>
<td>45.</td>
<td>P₃,₄ posterior trigonid wall: 0 = complete [taxa without metaconids are assigned this character state]; 1 = deeply notched.</td>
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<td>46.</td>
<td>P₃,₄ hypoconid size: 0 = large; 1 = small or absent.</td>
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<td>47.</td>
<td>P₃,₄ hypoconid (or distal terminus of oblique cristid) position: 0 = distal to protoconid; 1 = distal to metaconid, or between protoconid and metaconid</td>
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<td>48.</td>
<td>P₇* P₄ hypocristid shearing development: 0 = absent; 1 = weak; 2 = strong.</td>
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<td>49.</td>
<td>P₃ buccal cingulum development: 0 = absent; 1 = incomplete, broken at protoconid and hypoconid; 2 = complete.</td>
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<td>50.</td>
<td>Lower premolar inflation: 0 = not basally inflated; 1 = slightly basally inflated; 2 = very basally inflated.</td>
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<td>51.</td>
<td>P₄ exodaenodonty: 0 = not exodaenodont; 1 = slightly exodaenodont; 2 = very exodaenodont.</td>
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<td>52.</td>
<td>P₄ talonid length (ratio of midline m-d length of trigonid to m-d length of talonid): 0 = extremely short or non-existent (tri:tal ≥ 1.61); 1 = short (much shorter than trigonid) (tri:tal ≥ 1.27, &lt; 1.61); 2 = equal or slightly shorter in length to trigonid (tri:tal ≥ 0.92, &lt; 1.27); 3 = talonid longer than trigonid (tri:tal &lt; 0.91).</td>
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<td>53.</td>
<td>Premolar orientation: 0 = Crown bases vertical in lateral perspective; 1 = slightly oblique; 2 = strongly oblique, projecting medial over the anterior.</td>
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<td>54.</td>
<td>P₄ anterobuccal cingulum development: 0 = absent or trace; 1 = strong.</td>
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<td>55.</td>
<td>P₃ postprotoconid ridge: 0 = weak or absent; 1 = moderate; 2 = very strong.</td>
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<td>56.</td>
<td>P₄ postmetaconid ridge: 0 = weak or absent; 1 = moderate; 2 = very strong.</td>
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<td>57.</td>
<td>P₄ paraconid height: 0 = low; 1 = moderate; 2 = high (nearly as high as protoconid).</td>
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<tr>
<td>58.</td>
<td>P₃,₄ protoconid height: 0 = P₃ much lower than P₄; 1 = P₃ slightly lower than P₄; 2 = P₃ equal in height to P₄; 3 = P₃ higher than P₄.</td>
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<td>59.</td>
<td>P₃ to P₄ area: 0 = 0.45-0.59; 1 = 0.60-0.69; 2 = 0.70-0.79; 3 = 0.80.</td>
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<td>60.</td>
<td>P₄ m-d L/b-l W: 0 = (&lt; 0.95); 1 = (≥ 0.96, &lt; 1.14); 2 = (≥ 1.15, &lt; 1.20); 3 = (≥ 1.21, &lt; 1.35); 4 = (≥ 1.36, &lt; 1.46); 5 = (&gt; 1.47).</td>
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<td>61.</td>
<td>P₄ area to M₁ area: 0 = (&lt; 0.62); 1 = (≥ 0.63, &lt; 0.72); 2 = (≥ 0.73, &lt; 0.82); 3 = (≥ 0.83, &lt; 0.92); 4 = (≥ 0.93, &lt; 1.02); 5 = (&gt; 1.03).</td>
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<td>62.</td>
<td>P₃ root orientation: 0 = P₃,₄ roots aligned mesiodistally; 1 = P₃ root shifted laterally, P₄ mesial root aligned mesiodistally; 2 = P₃ roots aligned mesiodistally, P₄ mesial root shifted laterally. [Scored as missing if roots are single].</td>
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**Molars**

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<td>63.</td>
<td>M₃ root number: 0 = one; 1 = two.</td>
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<td>64.</td>
<td>M₃ trigonid width (ratio of buccolingual breadths of trigonid and talonid): 0 = much wider than talonid (≥ 1.11); 1 = widths similar (&lt; 1.11, &gt; 0.90); 2 = much narrower than talonid (≤ 0.90).</td>
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<tr>
<td>65.</td>
<td>M₃ trigonid width (based on relative buccolingual breadths): 0 = much wider than talonid (≥ 1.20); 1 = trigonid and talonid widths similar (≤ 1.20-1.05); 2 = trigonid narrower than talonid (&lt; 1.05).</td>
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<td>66.</td>
<td>M₁ paraconid position: 0 = mesiolingual, between protoconid and metaconid; 1 = mesial to metaconid.</td>
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<tr>
<td>67.</td>
<td>M₂ paraconid position: 0 = mesiolingual, between protoconid and metaconid; 1 = mesial to metaconid.</td>
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<tr>
<td>68.</td>
<td>M₃ paraconid position: 0 = mesiolingual, between protoconid and metaconid; 1 = mesial to metaconid.</td>
</tr>
<tr>
<td>m8-9-10</td>
<td>M2-3 paraconid location: 0 = widely spaced from the metaconid, 1 = twinned with metaconid.</td>
</tr>
<tr>
<td>m11</td>
<td>M1 parastylid (= premetacristid): 0 = absent, 1 = present.</td>
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<tr>
<td>m12</td>
<td>Molar metastylids (postmetacristids): 0 = absent, 1 = small, 2 = large.</td>
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<tr>
<td>m13</td>
<td>M3 hypoconulid: 0 = single, 1 = double.</td>
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<tr>
<td>m14</td>
<td>M3 heel: 0 = absent, 1 = narrower than talonid, 2 = approximately equal in width to talonid.</td>
</tr>
<tr>
<td>m15</td>
<td>Molar enamel surface: 0 = smooth, 1 = slightly crenulated, 2 = highly crenulated.</td>
</tr>
<tr>
<td>m16</td>
<td>M1 trigonid height (ratio of trigonid height to talonid height measured on the buccal aspect of the crown): 0 = higher than talonid ($\geq 1.20$), 1 = slightly higher than talonid ($\geq 1.10, &lt; 1.20$), 2 = trigonid and talonid of similar height (&lt; 1.10).</td>
</tr>
<tr>
<td>m17</td>
<td>M1-3 cusp relief: 0 = moderate to high, 1 = low.</td>
</tr>
<tr>
<td>m18</td>
<td>M1 trigonid lingual configuration: 0 = open, 1 = closed.</td>
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<tr>
<td>m19</td>
<td>M1 metacristid position: 0 = transversely aligned—lingual to protoconid, 1 = slightly distolingual to protoconid.</td>
</tr>
<tr>
<td>m20</td>
<td>M2 paraconid development: 0 = absent, 1 = small, 2 = large.</td>
</tr>
<tr>
<td>m21</td>
<td>M1-2 lateral protocristid orientation: 0 = runs toward metaconid, 1 = runs toward hypoflexid.</td>
</tr>
<tr>
<td>m22</td>
<td>M1 distal trigonid wall: 0 = complete, 1 = deeply notched by protoconid/metaconid sulcus, 2 = medial and lateral protocristid do not meet but no sulcus is visible.</td>
</tr>
<tr>
<td>m23</td>
<td>M2 distal trigonid wall: 0 = complete, 1 = deeply notched by protoconid/metaconid sulcus, 2 = medial and lateral protocristid do not meet but no sulcus is visible.</td>
</tr>
<tr>
<td>m24</td>
<td>M1-3 wear facet X: 0 = present, 1 = absent.</td>
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<td>m25</td>
<td>M1-2 entoconid: 0 = barely stands out on lingual talonid marginal crest, 1 = a small discrete cusp, 2 = a large cusp.</td>
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<tr>
<td>m26</td>
<td>M1-2 postentoconid sulcus: 0 = prominent, 1 = faintly visible, 2 = absent.</td>
</tr>
<tr>
<td>m27</td>
<td>M1 hypoconulid size: 0 = large, 1 = moderate, 2 = small, 3 = absent.</td>
</tr>
<tr>
<td>m28</td>
<td>M2 hypoconulid size: 0 = large, 1 = moderate, 2 = small, 3 = absent.</td>
</tr>
<tr>
<td>m29</td>
<td>M3 hypoconulid size: 0 = large, 1 = moderate, 2 = small, 3 = absent.</td>
</tr>
<tr>
<td>m30</td>
<td>M1-2 hypoconulid position: 0 = twinned to entoconid, 1 = near midline, 2 = slightly buccal to midline.</td>
</tr>
<tr>
<td>m31</td>
<td>M1-2 cristid obliqua development: 0 = weak (rounded), 1 = strong (trenchant), 2 = very strong (trenchant).</td>
</tr>
<tr>
<td>m32</td>
<td>M1 cristid obliqua orientation: 0 = reaches trigonid wall at a point distal to protoconid, 1 = reaches trigonid wall at a point distolingual to protoconid, 2 = reaches trigonid wall at a point distal to metaconid.</td>
</tr>
<tr>
<td>m33</td>
<td>M2 cristid obliqua orientation: 0 = reaches trigonid wall at a point distal to protoconid, 1 = reaches trigonid wall at a point distolingual to protoconid, 2 = reaches trigonid wall at a point distal to metaconid.</td>
</tr>
<tr>
<td>m34</td>
<td>M1 cristid obliqua terminus: 0 = runs to base of trigonid, 1 = runs part way up the distal trigonid wall, 2 = connects with protoconid tip or protocristid, 3 = connects with metaconid.</td>
</tr>
<tr>
<td>m35</td>
<td>M2 cristid obliqua terminus: 0 = runs to base of trigonid, 1 = runs part way up the distal trigonid wall, 2 = connects with protoconid tip or protocristid, 3 = connects with metaconid.</td>
</tr>
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</table>
95. m36. M3 cristid obliqua terminus: 0 = runs to base of trigonid; 1 = runs part way up the
distal trigonid wall; 2 = connects with protoconid tip or protocristid; 3 = connects with
metaconid.
96. m37. M1-2 centroconid development: 0 = present; 1 = absent.
97. m38*. M1-2 hypocristid development: 0 = absent or seen only as a trace; 1 = weak; 2 =
strong.
98. m39*. M3 hypocristid development: 0 = absent or seen only as a trace; 1 = weak; 2 =
strong.
99. m40*. Lingual configuration of M1-2 talonid: 0 = open; 1 = notched lingually but not open;
2 = closed.
100. m41. M1-2 distal fovea: 0 = absent; 1 = present (weak); 2 = present (large).
101. m42. M1-2 hypocristid configuration: 0 = simple; 1 = with accessory cusp close to
hypoconid.
102. m43. M1-2 cristid obliqua: 0 = notched; 1 = straight.
103. m44*. Molar cusp inflation: 0 = cusps not inflated, marginally positioned; 1 = slightly
inflated; 2 = very inflated.
104. m45*. M1-2 buccal cingulum development: 0 = absent to trace; 1 = partial, broken at
protoconid and hypoconid; 2 = complete.
105. m46*. M1 hypoflexid depth: 0 = very shallow; 1 = moderate; 2 = deep.
106. m47*. M2 hypoflexid depth: 0 = very shallow; 1 = moderate; 2 = deep.
107. m53*. Ratio of M3 length to M2 length: 0 = M3 much longer than M2 (0.71-0.80); 1 =
M3 longer than M2 (0.81-0.90); 2 = M3 equal than M2 (0.91-1.00); 3 = M3 smaller than M2
(1.01-1.12); 4 = M3 much smaller than M2 (≥ 1.13); 5 = if M3 absent.
108. m55*. M1 mesiodistal length/buccolingual breadth: 0 = 1.0-1.15; 1 = 1.16-1.22; 2 =
1.23-1.32; 3 = > 1.33.
109. m56. Convergence of buccal and lingual molar cusp walls: 0 = convergent; 1 =
vertically sided.
110. m57. M1-2 entoconid position relative to hypoconid: 0 = transverse to hypoconid; 1 =
distal to hypoconid.
111. ML88*. M1-3 Pre-entocristid: 0 = indistinct to absent; 1 = weakly developed (low); 2 =
well-developed (strong and high).

Upper Teeth:

**Incisors**

112. I1*. I1-I2 interstitial contact: 0 = absent; teeth widely spaced; 1 = present as narrow
contact; 2 = I2 tightly packed against I1, I1 preparacrista abbreviated.
113. I2. I1-I1 interstitial contact: 0 = present; 1 = absent: a wide space occurs in the midline
between these teeth.
114. I3. I2-C diastema: 0 = present; 1 = absent.
115. I4*. I1 area I2 area: 0 = areas approximately equal (≤ 1.00); 1 = I1 slightly larger than I2
(> 1.00, < 1.40); 2 = I1 much larger than I2 (> 1.40).
116. I5*. I1 size (I1 area M1 area): 0 = incisor small (≤ 0.50); 1 = incisor moderate (> 0.50,
< 0.56); 2 = incisor large (≥ 0.56).
117. I6*.  1\(^1\) occlusal shape (mesiodistal length/buccolingual breadth): 0 = rounded oval (< 1.05), 1 = buccolingually compressed (> 1.05, < 1.30); 2 = extremely compressed (> 1.30).

118. I7*.  1\(^2\) occlusal shape (mesiodistal length / buccolingual breadth): 0 = rounded oval (≤ 1.05); 1 = slightly buccolingually compressed (> 1.05, < 1.30); 2 = extremely buccolingually compressed (≥ 1.30).

119. I10.  1\(^1\) occlusal edge orientation (for spatulate incisors only; all others scored as "?"; 0 = occlusal edge orthogonal to long axis of root; 1 = occlusal edge wears at a steep angle to long axis of root; 2 = crown with pronounced mesial asymmetry (= mesial process) in unworn state.

120. I11.  1\(^1\)-1\(^2\) lingual cingulum: 0 = moderate, continuous; 1 = strong.

121. I12.  1\(^1\)-1\(^2\) basal lingual cusp: 0 = absent; 1 = present.

122. I13.  1\(^1\)-1\(^2\) buccal cingulum: 0 = absent; 1 = present.

**Canines**

123. C1.  C\(^1\) cross-sectional shape: 0 = oval; 1 = rounded.

124. C2*. Upper canine occlusion: 0 = C\(^1\) wears against P\(^1\)-P\(^2\); 1 = C\(^1\) wears against P\(^2\); 2 = C\(^1\) wears against P\(^2\)-P\(^3\); 3 = C\(^1\) wears against P\(^3\).

125. C3.  C\(^1\) mesial groove (females): 0 = shallow or absent; 1 = deep.

126. C4*. C\(^1\) lingual cingulum: 0 = weak or absent; 1 = strong; 2 = very strong.

**Premolars**

127. P1*.  P\(^2\) root number: 0 = one (if tooth is absent, taxon scored "0"); 1 = two; 2 = three.

128. P2.  P\(^3\) root number: 0 = two; 1 = three.

129. P3.  P\(^4\) root number: 0 = two; 1 = three.

130. P4*. Ratio of P\(^2\) area to P\(^3\) area: 0 = P\(^2\) much smaller (≤ 0.85) (if tooth is absent, taxon scored "0"); 1 = P\(^2\) smaller (> 0.85, ≤ 0.95); 2 = P\(^2\) equal (≥ 0.95); 3 = clearly larger.

131. P5*. Ratio of P\(^4\) area to M\(^1\) area: 0 = P\(^4\) << M\(^1\) (≤ 0.66); 1 = P\(^4\) < M\(^1\) (> 0.66, ≤ 0.76); 2 = P\(^4\) = M\(^1\) (0.77-1.05); 3 = P\(^4\) > M\(^1\) (> 1.06).

132. P6.  P\(^2\) occlusal outline: 0 = triangular; 1 = suboval with the long axis b-l; 2 = suboval with the long axis m-d; 3 = round.

133. P7.  P\(^4\) occlusal outline: 0 = triangular; 1 = suboval; 2 = squared.

134. P8.  P\(^3\)-P\(^4\) trigon/talon proportions: 0 = trigon >> talon; 1 = trigon < talon.

135. P9.  P\(^3\) protocone: 0 = present; 1 = absent.


137. P11.  P\(^3\) protocone: 0 = low relative to paracone; 1 = high relative to paracone.

138. P12.  P\(^4\) protocone: 0 = present; 1 = absent (if tooth absent, taxon scored "1").

139. P13*.  P\(^4\) hypocone: 0 = absent; 1 = present.

140. P14*.  P\(^4\) paraconule: 0 = large; 1 = small; 2 = absent.

141. P15.  P\(^3\)-P\(^4\) parastyles: 0 = present; 1 = absent.

142. P16.  P\(^3\)-P\(^4\) metastyles: 0 = absent; 1 = present.

143. P17.  P\(^3\)-P\(^4\) postprotocrista: 0 = strong; 1 = weak, short.
P18. P2-3 distal crown margin: 0 = smoothly rounded; 1 = waisted between buccal and lingual cusps.
P19. P3 lingual cingulum: 0 = absent or weak; 1 = strong.
P20. P, metacone: 0 = absent; 1 = present
P21. P3 buccal cingulum development: 0 = absent or weak; 1 = strong.
ML126*. P4 hypocone: 0 = minute to absent; 1 = present but small; 2 = strong.
ML127*. P3 hypocone: 0 = minute to absent; 1 = present but small; 2 = strong.

Molars
M1*. M1-2 root number: 0 = three, three; 1 = three, two; 2 = two, two.
M2*. M3 root number: 0 = three; 1 = two; 2 = one.
M3*. M2 shape (bl/nd): 0 = very transverse (> 1.65); 1 = transverse (< 1.65, > 1.30); 2 = squared (≤ 1.30).
M4*. Ratio of M1 area to M2 area: 0 = M1 >> M2 (≥ 1.40); 1 = M1 > M2 (< 1.40, > 1.0); 2 = M1 ≤ M2 (≤ 1.0).
M7*. M2 metaconule: 0 = absent, 1 = single; 2 = double.
M9*. M3 preprotoconule: 0 = absent; 1 = weak; 2 = strong.
M10*. M1 hypocone size: 0 = large; 1 = small; 2 = minute to absent.
M11*. M2 hypocone size: 0 = large; 1 = small; 2 = minute to absent.
M12*. M1 hypocone position: 0 = distal, far lingual to protocone; 1 = distal, slightly lingual to protocone; 2 = distal, slightly buccal to protocone.
M13*. M prehypocrista development: 0 = absent; 1 = weak; 2 = strong, reaches to postprotocrista, encloses the talon lingually.
M14. M3 prehypocrista development: 0 = absent; 1 = strong, reaches to postprotocrista, encloses the talon lingually.
M15. M1 or M2 paraconule position: 0 = attached to preprotocrista; 1 = unattached to preprotocrista.
M16*. M1 metaconule: 0 = absent to indistinct; 1 = small; 2 = moderate; 3 = large.
M17*. M1 mesostyle size: 0 = absent to indistinct; 1 = moderate; 2 = strong.
M17*. M1 mesostyle position: 0 = attached to ectocrista; 1 = present on buccal cingulum.
M20*. P4-M1 pericone: 0 = absent; 1 = small; 2 = large.
M22*. M3 lingual cingulum development: 0 = absent to indistinct; 1 = weak, broken; 2 = strong, complete.
M24*. M1 buccal cingulum development: 0 = absent to indistinct; 1 = weak; 2 = strong.
M27. M3 pre-metaconule cristae: 0 = absent or weak; 1 = strong
M28. M3 post-metaconule cristae: 0 = absent or weak; 1 = strong
M30*. M1 paraconule: 0 = absent; 1 = small-moderate; 2 = large
M31*. Molar protocone lingual inflation: 0 = not inflated; 1 = slightly inflated; 2 = very inflated.
M33*. M2 buccal expansion of paracone (specify which tooth): 0 = no expansion; 1 = slight expansion; 2 = considerable expansion.
173. M34*. M3 metacone: 0 = absent or very small; 1 = moderate (but smaller than paracone); 2 = large (equal to paracone).
174. M36*. M3 hypocone: 0 = absent or very small; 1 = small; 2 = large.
175. M37*. M1 paraconule size: 0 = absent; 1 = small-moderate (smaller than paracone); 2 = large (nearly as large as or larger than paracone).
176. M44*. M1 anterior cingulum: 0 = strong, complete, long (connected to parastyle); 1 = strong, short; 2 = weak or absent.
177. M46*. M1 size relative to M3: 0 = very small (half the size of M1 or less); 1 = small (two thirds); 2 = large (approximately as large).
178. ML147*. M1-2 metastyle: 0 = indistinct to absent; 1 = moderate; 2 = strong.
179. ML148*. M1-2 parastyle: 0 = indistinct to absent; 1 = moderate; 2 = strong.
180. ML149. M1-2 parastyle position: 0 = mesial to paracone; 1 = mesiobuccal to paracone.
181. ML150. M1-2 metastyle position: 0 = distal to metacone; 1 = distobuccal to metacone.
182. ML151. M1-3 posterior cingulum: 0 = moderate, does not reach the metastyle; 1 = connected to metastyle.
183. ML152*. M1-3 posterior margin (waisted between buccal and lingual cusps): 0 = indistinct to absent; 1 = present but shallow; 2 = present, deep.
184. ML153*. M1-2 postparacrista: 0 = indistinct to absent; 1 = weakly developed; 2 = well developed (but well-marked notch between postparacrista and premetacrista); 3 = strongly elevated (weak notch between postparacrista and premetacrista).
185. ML154*. M1-2 premetacrista: 0 = indistinct to absent; 1 = weakly developed; 2 = well developed (but well-marked notch between premetacrista and postparacrista); 3 = strongly elevated (weak notch between premetacrista and postparacrista).
186. ML155. M1-3 protocone arrangement: 0 = normal position; 1 = oblique.
187. ML156. M1-2 postprotocrista development: 0 = strong; 1 = tiny.
188. ML157*. M1 postprotocrista length: 0 = indistinct to absent; 1 = short; 2 = long.
189. ML158*. M2 postprotocrista length: 0 = indistinct to absent; 1 = short; 2 = long.
190. ML159. M1 postprotocrista direction: 0 = transverse, directed toward metaconule (or virtual metaconule emplacement); 1 = lateral, directed toward the lingual posterior cingulum (post-protocrista fold-like).
191. ML160. M2 postprotocrista direction: 0 = transverse, directed toward metaconule (or virtual metaconule emplacement); 1 = lateral, directed toward lingual posterior cingulum (post-protocrista fold-like).
192. ML161. M1 postprotocrista terminus: 0 = runs to base of metacone (with hypometacrista); 1 = runs to metacone (at the level of the small or virtual metacone); 2 = runs to posterior cingulum; 3 = limited at a point distal to protocone.
193. ML162. M2 postprotocrista terminus: 0 = runs to base of metacone (with hypometacrista); 1 = runs to metacone (at the level of the small or virtual metacone); 2 = runs to posterior cingulum; 3 = limited at a point distal to protocone.
194. ML163. M1-2 preprotocrista: 0 = low; 1 = elevated.
195. ML164. M1 preprotocrista connection (buccal side): 0 = connected to parastyle (by way of preparaconule crista); 1 = connected to paraconule (or near to it or to a virtual paraconule).
196. ML165. $M^2$ preprotocrista connection (buccal side): 0 = connected to parastyle (by way of preparaconule crista); 1 = connected to paraconule (or near to it or to a virtual paraconule).

197. ML166*. $M^{1-2}$ postparaconule crista: 0 = indistinct to absent; 1 = moderate; 2 = well-developed (connected to paracone).

198. ML168*. $M^{1-2}$ hypometacrista: 0 = absent; 1 = weakly developed (low and short); 2 = well-developed (high).

199. ML169*. $M^{1-2}$ hypoparacrista: 0 = absent; 1 = weakly developed (short); 2 = well-developed (high).

200. MLN*. Hypometaconulecrista: 0 = indistinct to absent; 1 = moderate (not connected to protocone); 2 = well-developed (connected to protocone or postprotocrista).

Cranial characters:

201. Cr 1. Transverse septum arising from the cochlear housing: 0 = Absent; 1 = present and forming the lateral wall of an anterior accessory cavity pneumatized from the tympanic cavity; 2 = present and forming the lateral wall of an anterior accessory cavity pneumatized from the epitympanic recess.

202. Cr 2. Extent of pneumatization of anterior accessory cavity: 0 = Anterior accessory cavity lies anterior to the tympanic cavity and is not trabeculated; 1 = anterior accessory cavity extends medial to the tympanic cavity, and is trabeculated.

203. Cr 3. Pneumatization of mastoid (from epitympanic recess?): 0 = absent; 1 = present.

204. Cr 4. Presence or absence of perbullar pathway: 0 = absent; 1 = present and formed exclusively by the petrosal bone.

205. Cr 5. Anteroposterior location of posterior carotid foramen in bulla: 0 = Posterior to line joining midpoints of tympanic bones; 1 = anterior to this line.

206. Cr 6*. Mediolateral position of posterior carotid foramen in bulla: 0 = medial; 1 = midline of the bulla; 2 = lateral.

207. Cr 7. Ventrodorsal position of the carotid foramen in the bulla: 0 = dorsal, adjacent to basioccipital or mastoid bone; 1 = ventral.

208. Cr 8*. Position of posterior carotid foramen relative to fenestra cochleae: 0 = posterior; 1 = ventral; 2 = anterior.

209. Cr 9. Position of the portion of the internal carotid/promontory artery (or its accompanying nerves) lying on the promontorium anterior to the fenestra cochleae: 0 = on ventrolateral surface of promontorium; 1 = contacting only the cupula of the cochlea.

210. Cr 10. Position of the portion of the internal carotid/promontory canal relative to the fenestra cochleae: 0 = runs across ventral lip of the fenestra cochleae, shielding it from ventral view when a canal is present; 1 = internal carotid canal does not shield the fenestra cochleae from ventral view.

211. Cr 11. Size of stapedial and promontory canals: 0 = both stapedial and promontory canals are large; 1 = stapedial slightly smaller than promontory; 2 = stapedial highly reduced or absent altogether, 3 = stapedial larger than promontory; 4 = both promontory and stapedial canals absent.

212. Cr 12. Morphology of promontory canal, when present: 0 = open trough; 1 = complete canal.

213. Cr 14. Position of ventral edge of the tympanic bone: 0 = intrabullar, or aphaneric; 1 = extrabullar or phaneric.
214. Cr 15. The shape of the tympanic bone: 0 = ribbon-like or only slightly expanded; 1 = laterally expanded into a collar or tube; ? = due to fusion with surrounding bones, of unknown shape.
215. Cr 16. Morphology of annular bridge: ? = This character is not analyzable in those taxa with an extrabullar tympanic, or those in which this region is not known; 0 = Linea semicircularis or partial annular bridge formed on a entotympanic bulla, 1 = linea semicircularis formed on a petrosal bulla, 2 = a complete annular bridge.
216. Cr 17. Encroachment of the auditory bulla on the pterygoid fossa: 0 = absent, 1 = present and formed by anterior accessory cavity, 2 = present and formed by the tympanic cavity.
217. Cr 18. Nature of contact between the lateral pterygoid plate and the bulla wall: 0 = absent; 1 = laminar; 2 = abutting.
218. Cr 19. Extent of contact between the lateral pterygoid plate and the bulla wall: 0 = slight; 1 = or very extensive.
219. Cr 20. Flange of basioccipital overlapping medial bulla wall: 0 = absent or minimal; 1 = extensive.
220. Cr 21. Suprameatal foramen: 0 = absent; 1 = present, small and in the posterior root of the zygomatic arch; 2 = present, large, and above the external auditory meatus.
222. Cr 23*. Size of orbits: 0 = small; 1 = large; 2 = extremely large.
223. Cr 24*. Postorbital closure: 0 = none; 1 = postorbital bar present; 2 = postorbital septum present.
224. Cr 25. Composition of the postorbital septum: 0 = zygomatic forms most of the septum; 1 = frontal forms most of the septum.
225. Cr 26. Zygomatic-lacrimal contact: 0 = present; 1 = absent.
226. Cr 27. Pronounced interorbital constriction: 0 = absent, 1 = present below olfactory tract.
227. Cr 28. Contact between lacrimal and palatine: 0 = present; 1 = separated by a large fronto-maxillary contact (and in some taxa, a small os planum of the ethmoid); 2 = separated by a large os planum.
228. Cr 29. Foramen rotundum: 0 = absent; 1 = present.
229. Cr 30. Position of lacrimal foramen: 0 = outside orbital margin, 1 = within the orbit or on the rim.
230. Cr 31. Metopic suture in adult: 0 = unfused; 1 = fused.
231. Cr 32. Orbital convergence: 0 = less convergent than primates; 1 = primate-like values for convergence.
232. Cr 33*. Posterior nasal spine: 0 = reduced or absent; 1 = small but distinct; 2 = robust and long.
233. Cr 34. Posterior palatine torus: 0 = present; 1 = absent.
234. Cr 35. Pyramidal processes: 0 = medially placed; 1 = laterally placed.
235. Cr 36*. Length of medial pterygoid plate: 0 = long medial pterygoid plate extending one-third to one half of the distance to the anterior surface of the bulla, 1 = short but distinct from lateral pterygoid plate for its entire dorsoventral extent, 2 = medial pterygoid plate entirely absent, or reduced to a low rugosity.
236. Cr 37. Snout length: 0 = long snouts; 1 = short snouts.
237. Cr 38. Maxillary depth: 0 = deep; 1 = shallow.
238. Cr 39. Complete symphyseal fusion: 0 = absent; 1 = present.
239. Cr 40. Temporomandibular joint morphology: 0 = biconcave and transversely wide; 1 = anteroposteriorly oriented trough.
240. Cr 41. Entoglenoid process morphology: 0 = weak or absent; 1 = strong.
241. Cr 42. Inter-incisor diastema width: 0 = broad and wider than that of extant haplorhines; 1 = narrow, haplorhine-like.
242. Cr 43. Coronoid height relative to condyle: 0 = very far above; 1 = slightly above or equal.
243. Cr 44*. Condyle height relative to toothrow: 0 = at level of toothrow; 1 = slightly above; 2 = well above toothrow.
244. Cr 45. Corpus robusticity: 0 = shallow; 1 = deep.
245. Cr 46. Zygomatico-parietal contact at pterion: 0 = no postorbital closure; 1 = zygomatico-parietal contact; 2 = alisphenoid-frontal contact.
246. Cr 48. Epitympanic crest: 0 = absent; 1 = present.
247. Cr 49. Broad ascending wing of premaxilla: 0 = narrow; 1 = broad.
248. Cr 50/301. Basioccipital stem: 0 = narrow; 1 = broad.
249. Cr 51/302. Choanal shape: 0 = narrow; 1 = broad.
250. Cr 52/292. Orientation of the mandibular symphysis: 0 = symphysis procumbent; 1 = symphysis erect.

**Postcranial characters:**

**Humerus**
251. H 1*. Shape of distal edge of the humeral trochlea: 0 = cylinder, distal edge perpendicular to shaft; 1 = distal edge somewhat angled to shaft; 2 = distal edge very angled.
252. H 2. Relative heights of medial and lateral edges of humeral trochlea: 0 = subequal; 1 = medial edge more flared than lateral edge.
253. H 3*. Trochleocapitular ridge: 0 = absent; 1 = weak but distinct; 2 = moderately distinct; 3 = very distinct.
254. H 4. Waisted trochlea (Minimum trochlear diameter/maximum trochlear diameter x 100): 0 = > 70 (unwaisted); 1 = ≤ 70 (waisted).
255. H 5*. Width of capitulum relative to trochlea (100 x ventral capitulum width/ventral trochlear width): 0 = < 100; 1 = between 100 and 140; 2 = 140-200; 3 = greater than 200.
256. H 6. Entepicondylar foramen: 0 = present; 1 = variable; 2 = absent.
257. H 7. Entepicondylar foramen position: 0 = above medial epicondyle; 1 = above ventral trochlea; 2 = above dorsal trochlea.
258. H 8. Medial epicondyle size: 0 = reduced; 1 = prominent.
260. H 10*. Shape of the lateral edge of the dorsal trochlea: 0 = not pronounced; 1 = moderately pronounced; 2 = very pronounced.
261. H 10†*. Shape of the medial edge of the dorsal trochlea: 0 = not pronounced; 1 = moderately pronounced; 2 = very pronounced.
262. H 11*. Dorsoepitrochlear fossa: 0 = present (strong); 1 = small, shallow; 2 = absent.
263. H 12*. Olecranon fossa shape: 0 = shallow; 1 = moderate; 2 = deep.
264. H 14*. Brachialis flange: 0 = broad; 1 = moderate; 2 = narrow.
266. H 18/. Capitular tail: 0 = ventral articular width < 2.5 times the ventral capitular width; 1 = ventral articular width > 2.5 times the ventral capitular width.
267. H 19*/. Ratio of humerus length to femur length (H/F): 0 = 100* H/F ≤ 65; 1 = H/F > 65, ≤ 80; 2 = H/F > 80.
Carpal bones

268. W2. Ulnar-pisiform articulation: 0 = Facet on pisiform for ulnar styloid process is roughly equal in size to that for triquetrum; 1 = Facet on pisiform for ulnar styloid process is much enlarged and deeply excavated.

Os pelvis

269. OP1/299. Gluteal tuberosity: 0 = present; 1 = absent.
270. OP2/300. Position of posterior gluteal tuberosity: 0 = Proximal to or level with lesser trochanter; 1 = distal to lesser trochanter.

Femur

271. F1*. Length of femoral neck: 0 = < 75; 1 = 75-120; 2 = > 120.
272. F2*. Angle of femoral neck: 0 = < 60; 1 = 60-70; 2 = > 70.
273. F3. Angle of lesser trochanter: 0 = medial (0-30°), 1 = posterior (>30°).
274. F4*. Size of third trochanter: 0 = large; 1 = small; 2 = low crest or absent.
275. F5*. Knee index (Antero-posterior diameter of distal femur/ mediolateral diameter of distal femur): 0 = < 90 (shallow knee); 1 = 90 – 100; 2 = > 100 (deep knee).
276. F6*. Femoral head shape: 0 = spherical; 1 = semicylindrical; 2 = cylindrical.
277. F7. Anterior extension of greater trochanter: 0 = no extension; 1 = extension present.
278. F8. Anterior bend of proximal femur: 0 = none; 1 = bent.
279. F9*. Relative length of trochanteric fossa: 0 = long (> 125); 1 = moderate (110-125); 2 = very short (< 110).
281. F11*. Size of lesser trochanter: 0 = large; 1 = intermediate; 2 = small.

Tibia

283. T1'. Fusion of tibia and fibula: 0 = absent; 1 = present.
284. T1"*. Articulation tibia/fibula: 0 = small; 1 = moderate; 2 = extensive.
286. T4*. Rotation of the medial malleolus: 0 = none; 1 = slight; 2 = strong.
287. T5*. Shape of medial malleolar articular surface: 0 = flat; 1 = anteriorly convex, posteriorly flat; 2 = all convex.
288. T6. Shape of distal tibial shaft: 0 = no compression; 1 = anteroposteriorly compressed.
289. T7. Position of tibialis posterior groove: 0 = on medial side of malleolus; 1 = on posterior side of malleolus.

Talus

290. A1. Position of the flexor hallucis longus groove: 0 = lateral to trochlea; 1 = central to trochlea.
291. A2"*. Shape of talo-fibular facet: 0 = steep-sided; 1 = steep-sided with a platar lip; 2 = sloped obliquely.
292. A4"*. Development of the talar posterior trochlear shelf: 0 = none; 1 = weakly developed; 2 = well developed (prominent).
293. A5'. Talar neck length (NL/TL x 100): 0 = short (< 50); 1 = long (> 50).
294. A6. Medial talo-tibial facet: 0 = short (does not reach to plantar edge of bone); 1 = long.
295. A7/295. Lateral talar trochlear asymmetry: 0 = absent; 1 = present.
296. A8/296. Talar cotylar fossa: 0 = shallow; 1 = deep, medially projecting.
297. A9'/297. Width of the head of the talus (HW/HHT x 100): 0 = < 120; 1 = > 120.
298. GEB1*. Talar neck angle: 0 = < 20°; 1 = 20-30°; 2 = > 30°.
299. GEB2*. Talar body height (HT/MTRW x 100): 0 = < 100; 1 = 100-120; 2 = 120-150.
300. GEB3*. TW/TL x 100: 0 = < 60; 1 = > 60.

Calcaneus
301. C1*. Anterior calcaneal elongation: 0 = not elongate (ACL or anterior calcaneal ratio < 40); 1 = moderate (ACL ≥ .40-.45); 2 = long (> .45).
302. C2*. Position of the peroneal tubercle: 0 = distal to joint; 1 = at joint; 2 = proximal to joint.
304. C4/298. Calcaneo-cuboid articulation: 0 = articular wedge absent (fan-shaped); 1 = articular wedge present (more circular).

Navicular
305. N1*. Length relative to width: 0 = short (<90); 1 = moderate (100-150), 2 = long (>150).
306. N3. Morphology of the naviculocuboid articulation: 0 = cuboid facet on navicular contacts only the ectocuneiform; 1 = cuboid facet contacts the ectocuneiform and mesocuneiform facet.

Entocuneiform
307. E1*. Shape of Entocuneiform/MT1 articulation: 0 = dorsally reduced; 1 = dorsal moiety of joint enlarged relative to ventral moiety; 2 = dorsal moiety greatly enlarged.
308. E2. Lateral process of entocuneiform: 0 = small; 1 = hypertrophied.

General Foot
309. O1. Foot axis: 0 = mesaxonic; 1 = paraxonic; 2 = ectaxonic.
310. O2. Toilet claw: 0 = absent; 1 = present.
311. O3. Prehallux: 0 = present; 1 = absent.
312. O4. Metatarsus length: 0 = short; 1 = long.

Metatarsal
313. MT1*. Peroneal tubercle of MT1: 0 = very large; 1 = large; 2 = small.
314. MT2. Hallux length: 0 = short; 1 = long.

Visual system:
315. V1/288. Optic fovea: 0 = absent; 1 = present.
316. V2/290. Tapetum lucidum: 0 = present; 1 = absent.

Miscellaneous other characters:
317. Haplorni vs strepsirrhine: 0 = strepsirrhine; 1 = haplorhine.

Molecular and physiological:
318. MOL1/303. SINE (short interspersed nuclear elements) markers at the human locations 12p13-pter on chromosome 12: 0 = SINE absent, 1 = SINE present.
319. MOL2/304. SINE (short interspersed nuclear elements) markers at the human location 7q22, on chromosome 7: 0 = SINE absent; 1 = SINE present.
320. MOL4/291. Ability to synthesize Vitamin C: 0 = synthesis possible; 1 = synthesis not possible.

Placentation:

321. PL1/305. Placentation: 0 = Diffuse, epitheliochorial; 1 = Discoidal, hemochorial.
322. PL2/306. Blastocyst attachment: 0 = noninvasive; 1 = invasive.
324. PL4/308. Choriovitelline placenta: 0 = present; 1 = absent.
325. PL5/309. Embryonic body stalk: 0 = absent; 1 = present.
326. PL6/310. Allantois development: 0 = large, vesicular; 1 = rudimentary.

Character sources:

- For details about the source of most characters: Ross et al., 1998, Kay et al., 2004;
- MOL1/303, MOL2/304, MOL3/305: Schmitz & Zischler, 2004;
- MOL4/291: Pollock & Mullin, 1987;
- 289: Pocock, 1918;
- V1/288, V2/290: Martin, 1990;
- Cr52/292: Beard et al., 1994;
- A1, A2’, A4, A5’, A6, GEB1-3: Gebo et al., 2001;