

## Supplementary Online Material 1:

### Characters and character states used in the phylogenetic analysis.

This supplementary data file derives from Kay (2015).

Characters followed by an asterisk are "ordered." Ordered characters are scaled by the number of character states, such that the sum of the steps in the morphocline equals 100. This weight is indicated as "weight = number". To maintain consistency for more broadly-based phylogenetic analyses, many characters that may be invariable in platyrrhines but are informative within Anthroponoidea or Primates as a whole were included. Likewise the weighting scheme is based upon the broader context of living and fossil primate taxa.

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#### Cranial characters

##### *Paranasal Sinuses*

1. (Weight= 100). Ethmoidal sinus (Type II): 0= present; 1= absent.
2. (Weight= 100). Splenoidal sinus (Type I): 0= present; 1= absent.
3. (Weight= 100). Maxillary sinus: 0= present; 1= absent.
4. (Weight= 100). Anterior ethmoidal sinus: 0= present; 1= absent.
5. (Weight= 100). Sphenoidal sinus: 0= present; 1= absent.

### *Zygomatic region*

- 6.\* (Weight= 50). Zygomatico-facial foramen (character 27 in Horovitz, 1999): 0= small relative to M1 breadth; 1= large relative to M1 breadth; 2= very large relative to M1 breadth.
7. (Weight= 100). Zygomatic arch position (character 23 in Horovitz, 1999): 0= above the alveolar border of the maxilla; 1= below the alveolar border.
8. (Weight= 100). Extent of inferior orbital fissure (character 84 in Horovitz, 1999): 0= ventrolateral limit of the inferior orbital fissure does not reach the zygomatic arch; 1= the ventrolateral limit of the inferior orbital fissure reaches the zygomatic arch.
9. (Weight= 100). Zygomatico-parietal contact at pterion (cranial character 46 in Kay et al., 2004): 0= no postorbital closure; 1= zygomatico-parietal contact; 2= alisphenoid-frontal contact.

### *Lacrimal Region*

10. (Weight= 100). Position of lacrimal foramen (cranial character 30 in Kay et al., 2004): 0= outside orbital margin; 1= within the orbit or on the rim.
- 11.\* (Weight= 50). Extraorbital exposure of the lacrimal: 0= lacrimal fossa is completed anteriorly by maxillary; 1= lacrimal has some facial exposure; 2= lacrimal contacts nasal (excludes maxillary-frontal contact).
12. (Weight= 100). Zygomatic-lacrimal contact (cranial character 26 in Kay et al., 2004): 0= present on ventral orbital rim; 1= absent on ventral orbital rim.
13. (Weight= 100). Contact between lacrimal and palatine bones (cranial character 28 in Kay et al., 2004): 0= contact present; 1= lacrimal and palatine separated; contact between frontal and maxilla contact (or in some taxa, by a small os planum of the ethmoid); 2= separated by a large os planum.

### *Facial region*

- 14.\* (Weight= 50). Position of the infraorbital foramen relative to the Frankfurt horizontal plane (character 26 in Horovitz, 1999): 0= posterior to P4; 1= positioned above P4 through P3; 2= positioned above P2.
- 15.\* (Weight= 50). Angle of cranial kyphosis (Lieberman et al., 2000): 0= ( $\leq 140^\circ$ ); 1= ( $> 140^\circ, < 155^\circ$ ); 2= ( $\geq 155^\circ$ ).
16. (Weight= 100). Nasal fossa width (character 25 in Horovitz, 1999): 0= narrower than the palate width; 1= broader than the palate width.
17. (Weight= 100). Nasal capsule (Maier, 1980): 0= processus alaris superior present; 1= processus alaris superior absent.
18. (Weight= 100). Snout length (cranial character 37 in Kay et al., 2004): 0= long snout; 1= short snout.
19. (Weight= 100). Maxilla depth (cranial character 38 in Kay et al., 2004): 0= deep; 1= shallow.
20. (Weight= 100). Inter-incisor diastema width (cranial character 42 in Kay et al., 2004): 0= broad and wider than that of extant haplorhines; 1= narrow, haplorhine-like.
21. (Weight= 100). Ascending wing of premaxilla (cranial character 49 in Kay et al., 2004): 0= narrow; 1= broad.

### *Temporomandibular region*

- 22.\* (Weight= 50). Postglenoid foramen (character 12 in Horovitz, 1999): 0= absent; 1= small; 2= large.
23. (Weight= 100). Temporomandibular joint morphology (cranial character 40 in Kay et al., 2004): 0= biconcave and transversely wide; 1= anteroposteriorly oriented trough.

24.\* (Weight= 50). Postglenoid process size (100 times postglenoid process length divided by prosthion-inion length) (cranial character 41 in Kay et al., 2004): 0= weak or absent ( $< 0.39$ ); 1= strong ( $\geq 0.39, < 0.69$ ); 2= very strong ( $\geq 0.69$ ).

*Pterygoid and palatal region*

25.\* (Weight= 50). Palate shape: 0= v-shaped (the distance between lingual surfaces of the upper canines divided by the between the lingual surfaces of the upper second molars is  $< 0.39$ ); 1= intermediate (ratio values of  $\geq 0.39, \leq 0.64$ ); 2= approaches parallel (ratio values  $> 0.64$ ).

26. (Weight= 100). Interpterygoid fossa (Du Brul, 1965): 0= deep; 1= shallow.

27.\* (Weight= 50). Length of medial pterygoid plate (cranial character 36 in Kay et al., 2004): 0= long medial pterygoid plate extending one-third to one half of the distance to the anterior surface of the bulla enclosing a large fossa between medial and lateral pterygoids; 1= short but distinct from lateral pterygoid plate for its entire dorsoventral extent. Ventrally, there is a hamular process; more dorsally the plate merges with the lateral plate or if distinct, the fossa is slit-like; 2= medial pterygoid plate entirely absent, or reduced to a low rugosity. Only the hamulus is present.

28. (Weight= 100). Encroachment of the auditory bulla on the pterygoid fossa (cranial character 17 in Kay et al., 2004): 0= no encroachment; 1= encroachment by the anterior accessory cavity; 2= present and formed by the tympanic cavity.

29. (Weight= 100). Nature of contact between the lateral pterygoid plate and the bulla wall (cranial character 18 in Kay et al., 2004) : 0= absent; 1= laminar; 2= abutting.

30. (Weight= 100). Extent of contact between the lateral pterygoid plate and the bulla wall (cranial character 19 in Kay et al., 2004): 0= slight; 1= or very extensive.

31. (Weight= 100). Pyramidal process of palate and post-alveolar notch: 0= no post-alveolar notch between the pyramidal process and the maxillary tuberosity; 1= offset from maxillary tuberosity by a distinct post-alveolar notch.

- 32.\* (Weight= 50). Mediolateral position of pyramidal processes (100 times the ratio of inter-pyramidal breadth to outer M1 palate breadth) (cranial character 35 in Kay et al., 2004): 0= medially placed ( $\leq 43$ ); 1= intermediate ( $> 43, \leq 64$ ); 2= laterally placed ( $> 64$ ).
33. (Weight= 100). Posterior palatine torus (cranial character 34 in Kay et al., 2004): 0= present; 1= absent.
- 34.\* (Weight= 50). Posterior nasal spine (cranial character 33 in Kay et al., 2004): 0= reduced or absent; 1= small but distinct; 2= robust and long.
35. (Weight= 100). Posterior extent of the turbinates: 0= extend posterior to the palatine; 1= completely anterior to the palatine.
36. (Weight= 100). Angle of the incisive canal in palate: 0= obliquely oriented with respect to the plane of the palate; 1= more closely resembles a right angle with the palate.

#### *Temporal fossa*

37. (Weight= 100). Temporal emissary foramen (character 20 in Horovitz, 1999): 0= present and large; 1= small or absent.

#### *Nucal region*

- 38.\* (Weight= 50). Paroccipital processes: 0= forms a distinct shelf or process; 1= forms a raised ridge; 2= weak or absent.
39. (Weight= 100). Pneumatization of mastoid (cranial character 3 in Kay et al., 2004): 0= absent; 1= present.

#### *Orbital region*

- 40.\* (Weight= 50). Lateral cranial profile at glabella: 0= depressed; 1= flat; 2= convex.
41. (Weight= 100). Interorbital fenestra: 0= absent; 1= present.
- 42.\* (Weight= 50). Size of orbits (cranial character 23 in Kay et al., 2004): 0= small; 1= large; 2= extremely large.
43. (Weight= 50). Orbital convergence (Ross, 1996): 0= (< 55°); 1= (55°-65°); 2= (> 65°).
- 44.\* (Weight= 50). Interorbital breadth: 0= narrow; 1= broad; 2= extremely broad.
45. (Weight= 100). Exposure of vomer in orbit: 0= unexposed; 1= exposed.
46. (Weight= 100). Postorbital closure (cranial character 24 in Kay et al., 2004): 0= none; 1= postorbital bar present; 2= postorbital septum present.
47. (Weight= 100). Composition of the postorbital septum (cranial character 25 in Kay et al., 2004): 0= zygomatic forms most of the septum; 1= frontal forms most of the septum.
48. (Weight= 100). Position of interorbital constriction relative to olfactory tract (cranial character 27 in Kay et al., 2004): 0= absent; 1= present below olfactory tract.
49. (Weight= 100). Foramen rotundum (cranial character 29 in Kay et al., 2004): 0= superior orbital fissure transmits maxillary nerve; 1= separate foramen (f. rotundum) for maxillary nerve.
50. (Weight= 100). Metopic suture in adults (cranial character 31 in Kay et al., 2004): 0= unfused; 1= fused.

#### *Ear region*

51. (Weight= 100). Cochlear housing as exposed in middle ear (character 15 in Horovitz, 1999): 0= singular; 1= dual.
52. (Weight= 100). Transbullar septa (character 14 in Horovitz, 1999): 0= ventrolateral region of middle ear without septa; 1= anteroventral region with septa.
53. (Weight= 100). Transverse septum arising from the cochlear housing (cranial character 1 in Kay et al., 2004): 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.

54. (Weight= 100). Extent of pneumatization of anterior accessory cavity (cranial character 2 in Kay et al., 2004): 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.
55. (Weight= 100). Presence or absence of perbullar pathway for the internal carotid artery (cranial character 4 in Kay et al., 2004): 0= absent; 1= present and formed exclusively by the petrosal bone.
56. (Weight= 100). Anteroposterior location of posterior carotid foramen in bulla (cranial character 5 in Kay et al., 2004): 0= posterior to line joining midpoints of tympanic bones; 1= anterior to this line.
- 57.\* (Weight= 50). Mediolateral position of posterior carotid foramen in bulla (cranial character 6 in Kay et al., 2004): 0= medial; 1= midline of the bulla; 2= lateral.
58. (Weight= 100). Ventrodorsal position of the carotid foramen in the bulla (cranial character 7 in Kay et al., 2004): 0= dorsal, adjacent to basioccipital or mastoid bone; 1= ventral.
59. (Weight= 100). Position of posterior carotid foramen relative to fenestra cochleae (cranial character 8 in Kay et al., 2004): 0= posterior; 1= ventral; 2= anterior.
60. (Weight= 100). Position of the internal carotid canal relative to the fenestra cochleae (cranial character 9 in Kay et al., 2004): 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.
61. (Weight= 100). Position of the portion of the internal carotid / promontory artery (or its accompanying nerves) lying on the promontorium anterior to the fenestra cochleae (cranial character 10 in Kay et al., 2004): 0= on ventrolateral surface of promontorium; 1= contacting only the cupula of the cochlea.
62. (Weight= 100). Size of stapedial and promontory canals (cranial character 11 in Kay et al., 2004): 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.
63. (Weight= 100). Morphology of promontory canal, when present (cranial character 12 in Kay et al., 2004): 0= open trough; 1= complete canal.
64. (Weight= 100). Canal for internal carotid artery or nerves (cranial character 13 in Kay et al., 2004): 0= absent; 1= present.
65. (Weight= 100). Position of ventral edge of the tympanic bone (cranial character 14 in Kay et al., 2004): 0= intrabullar or aphaneric; 1= extrabullar or phaneric.
66. (Weight= 100). The shape of the tympanic bone (cranial character 15 in Kay et al., 2004): 0= ribbon-like or only slightly expanded; 1= laterally expanded into a collar or tube.
67. (Weight= 100). Morphology of annular bridge (cranial character 16 in Kay et al., 2004): 0= Linea semicircularis or partial annular bridge formed on the entotympanic bulla; 1= Linea semicircularis formed on the petrosal bulla; 2= a complete annular bridge present.
68. (Weight= 100). Flange of basioccipital overlapping medial bulla wall (cranial character 20 in Kay et al., 2004): 0= absent or minimal; 1= extensive.
69. (Weight= 100). Basioccipital stem (character discussed in Beard and MacPhee, 1994): 0= narrow; 1= broad.
70. (Weight= 100). Suprameatal foramen (cranial character 21 in Kay et al., 2004): 0= absent; 1= present, small and in the posterior root of the zygomatic arch; 2= present, large, and above the external auditory meatus.
71. (Weight= 100). Patent parotic fissure (cranial character 22 in Kay et al., 2004): 0= present; 1= absent.
72. (Weight= 100). Enclosure of intratympanic portion of facial nerve in a bony canal (cranial character 47 in Kay et al., 2004): 0= no canal, facial runs in a sulcus; 1= bony canal present.
73. (Weight= 100). Epitympanic crest (cranial character 48 in Kay et al., 2004): 0= absent; 1= present.

### *Brain and internal cranial characters*

74. (Weight= 100). Tentorium cerebelli ossification (character 13 in Horovitz, 1999): 0= absent; 1= present.
75. (Weight= 100). Vascular canal connecting sigmoid sinus with subarcuate fossa (Cartmill's canal of Kay et al., 2008b) (character 17 in Horovitz, 1999): 0= absent; 1= present.
- 76.\* (Weight= 50). Size of olfactory bulbs: 0= large olfactory lobe; 1= moderate olfactory lobe; 2= small olfactory lobe.
- 77.\* (Weight= 50). Relative brain size: 0= small; 1= large; 2= very large.

### *Mandible*

78. (Weight= 100). Symphyseal orientation: 0= more horizontal orientation of planum alveolare; 1= more vertically oriented relative to planum alveolare.
- 79.\* (Weight= 50). Lateral profile of mandible (ratio of mandible depth [measured buccally] at p2 and m2): 0= superior and inferior border of the mandibular corpus are essentially parallel from the premolar to the mandibular angle ( $\leq 1.26$ ); 1= inferior border deepens posteriorly ( $> 1.26, \leq 1.72$ ); 2= "hyper-deep" ( $> 1.72$ ).
80. (Weight= 100). Mandibular corpus depth (cranial character 45 in Kay et al., 2004): 0= shallow; 1= deep.
81. (Weight= 100). Symphyseal fusion in young adult (cranial character 39 in Kay et al., 2004): 0= absent; 1= present.
- 82.\* (Weight= 50). Coronoid height relative to condyle: 0= very far above condyle; 1= above the level of condyle; 2= slightly above or equal to coronoid.
- 83.\* (Weight= 50). Condyle height relative to tooth row (cranial character 44 in Kay et al., 2004): 0= at level of tooth row; 1= slightly above; 2= well above tooth row.

- 84.\* (Weight= 50). Angle of the mandible: 0= hook-shaped angle; 1= moderately expanded angle; 2= extremely expanded angle.
85. (Weight= 100). Depth of the coronoid-condylar notch: 0= deep; 1= shallow.

## Permanent dentition

### *Lower incisors*

86. i1.\* (Weight= 33). Lower incisor number: 0= three; 1= two; 2= one: i1 present, i2 absent; 3= lower incisors absent.
87. i2. (Weight= 100). Lower incisor occlusal arrangement: 0= edges wear flat producing an arcuate battery from lateral perspective; 1= cusp tips staggered.
88. i3. (Weight= 100). Lower incisor crown spacing: 0= no space; 1= spaces present between crowns.
89. i4. (Weight= 100). I2-c1 diastema: 0= present; 1= absent.
90. i5.\* (Weight= 50). i1-2 size (ratio of i1-2 area to m2 area): 0= very small ( $\leq 0.69$ ); 1= moderate sized ( $\geq 0.70, \leq 1.07$ ); 2= large ( $> 1.07$ ).
91. i6.\* (Weight= 33). i1: i2 proportions (ratio of i1 area to i2 area): 0= i1 much smaller than i2 ( $< 0.71$ ); 1= i1 smaller than i2 ( $\geq 0.71, < 0.78$ ); 2= i1 almost as large as i2 ( $\geq 0.78, < 1.00$ ); 3= i1  $>$  i2 ( $\geq 1.01$ ).
92. i7.\* (Weight= 50). i1 crown width (spatulate incisors only): 0= considerably wider (mesiodistally) than root (spatulate); 1= narrow at apex, but still wider than root; 2= "styliform" (crown apex approximately the same width as the cervical margin).
93. i8. (Weight= 100). i2 crown cross-sectional shape (ratio of mesiodistal length to buccolingual breadth): 0= rounded oval ( $\geq 0.64$ ); 1= mesiodistally compressed ( $< 0.64$ ).

94. i9.\* (Weight= 50). Lower incisor crown height (crown heights judged from cemento-enamel junction to crown tip on the buccal surface): 0= low crowned; 1= moderately high crowned; 2= high crowned.
95. i10. (Weight= 100). i1-2 crown buccal outline: 0= gently curved in lateral perspective; 1= acutely curved.
96. i11.\* (Weight= 50). Lower incisor roots: 0= erect or vertical; 1= slightly procumbent; 2= very procumbent.
97. i12.\* (Weight= 50). Lower incisor crowns: 0= erect or vertical; 1= procumbent; 2= very procumbent.
98. i13.\* (Weight= 50). Tooth comb: 0= absent; 1= with three teeth; 2= with two teeth.
99. i14. (Weight= 100). i1 crown shape: 0= spatulate; 1= lanceolate, pointed.
100. i15. (Weight= 100). i2 heel development (a lingual swelling at the base of crown): 0= heel absent; 1= heel present.
101. i16. (Weight= 100). Incisor lingual enamel: 0= well developed; 1= poorly developed or absent.
102. i17.\* (Weight= 50). Lower incisor lingual cingulum: 0= absent to weak; 1= strong but incomplete; 2= strong and complete.
103. i19.\* (Weight= 50). i1 area to m1 area: 0= i1 very small (ratio  $\leq 0.32$ ); 1= moderately enlarged ( $> 0.32, \leq 0.40$ ); 2= very enlarged ( $> 0.40$ ).

#### *Lower canines*

104. c1.\* (Weight= 33). Female c1 size (area relative to molars): 0= very small ( $c1 / m1 < 0.40$ ); 1= moderate ( $\geq 0.4, < 0.80$ ); 2= large ( $\geq 0.80, \leq 1.20$ ); 3= very large ( $> 1.20$ ).
105. c2.\* (Weight= 50). c1 dimorphism (square root male c1 area divided by square root of female c1 area): 0= low ( $< 1.07$ ); 1= moderate ( $\geq 1.07, < 1.17$ ); 2= high ( $\geq 1.17$ ).
106. c3. (Weight= 100). c1 cross-sectional shape: 0= rounded oval (mesiodistal / buccolingual,  $> 1.00, < 1.90$ ); 1= mesiodistally compressed (ratio  $\geq 1.90$ ).
107. c4. (Weight= 100). c1 lingual crest development: 0= rounded; 1= sharp.

108. c5. (Weight= 100). 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.
109. c6.\* (Weight= 50). Canine height (females): 0= low, squat; 1= narrow, short; 2= tall, at or above tooth row.

*Lower premolars*

110. p1. (Weight= 100). P1/p1: 0= present; 1= absent.
111. p2. (Weight= 100). p2: 0= present; 1= absent.
112. p3. (Weight= 100). p2 roots: 0= single; 1= double.
113. p4.\* (Weight= 50). p3-4 roots: 0= p3 single, p4 single; 1= p3 single, p4 double; 2= p3 double, p4 double.
114. p5.\* (Weight= 50). Premolar crowding (overlapping of crowns): 0= no crowding; 1= slightly crowded; 2= very crowded.
115. p6.\* (Weight= 50). p3 paraconid: 0= large; 1= small; 2= absent or extremely small.
116. p7.\* (Weight= 50). p4 paraconid: 0= large; 1= small; 2= absent or extremely small.
117. p9.\* (Weight= 33). p4 paraconid position: 0= mesial to protoconid; 1= mesiolingual, between protoconid and metaconid; 2= mesial to metaconid; widely spaced from metaconid; 3= twinned with metaconid.
118. p11.\* (Weight= 50). p3-4 cristid obliqua: 0= absent; 1= weak; 2= strong.
119. p13. (Weight= 100). 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.
120. p14. (Weight= 100). p4 metaconid position: 0= close to protoconid; 1= widely spaced from protoconid.
121. p15.\* (Weight= 50). p2 metaconid size: 0= absent or trace; 1= small; 2= large.
122. p16.\* (Weight= 50). p3 metaconid size: 0= absent or trace; 1= small; 2= large.

123. p17.\* (Weight= 50). p4 metaconid size: 0= absent or trace; 1= small; 2= large, almost as tall as protoconid.
124. p18. (Weight= 100). p4 trigonid - lingual wall: 0= basin closed by a premetacristid; 1= open with premetacristid absent or short.
125. p19.\* (Weight= 50). p3 entoconid and lingual talonid crest: 0= absent; 1= lingual talonid crest present but an entoconid does not stand out above it; 2= entoconid is a small discrete cusp.
126. p20.\* (Weight= 50). p4 entoconid and lingual talonid crest: 0= absent; 1= lingual talonid crest present but an entoconid does not stand out above it; 2= entoconid is a small discrete cusp.
127. p21. (Weight= 100). p4 lateral and medial protocristid: 0= continuous between metaconid and protoconid; 1= discontinuous between metaconid and protoconid.
128. p22. (Weight= 100). p3 lateral protocristid orientation: 0= transversely oriented; 1= distolingually oriented.
129. p23a. (Weight= 100). p4 lateral protocristid: 0= present; 1= absent.
130. p23. (Weight= 100). p4 lateral protocristid orientation: 0= transversely oriented; 1= distolingually oriented.
131. p24. (Weight= 100). p3-4 posterior trigonid wall: 0= complete (taxa without metaconids are assigned this character state); 1= deeply notched.
132. p25. (Weight= 100). p3-4 hypoconid size: 0= large; 1= cristiform, small, or absent.
133. p26. (Weight= 100). p3-4 hypoconid (or distal terminus of oblique cristid) position: 0= distal to protoconid; 1= distal to metaconid, or between protoconid and metaconid.
134. p26a. (Weight= 100). p4 talonid breadth: 0= narrow; 1= broad.
135. p27. (Weight= 100). p4 hypocristid shearing development: 0= weak or absent; 1= strong.
136. p28.\* (Weight= 50). p2 buccal cingulum development: 0= absent; 1= incomplete, broken at protoconid and hypoconid; 2= complete.

137. p29. (Weight= 100). Lower premolar inflation: 0= cusps marginal, not basally inflated; 1= crown surfaces constricted, cusp margins sloping.
138. p30.\* (Weight= 50). p4 exodaenodonty: 0= not exodaenodont; 1= slightly exodaenodont; 2= very exodaenodont.
139. p31.\* (Weight= 33). p4 talonid length (ratio of midline mesiodistal length of trigonid to mesiodistal length of talonid): 0= extremely short or non-existent ( $\text{tri:tal} \geq 1.61$ ); 1= short (much shorter than trigonid) ( $\text{tri:tal} \geq 1.27, < 1.61$ ); 2= equal or slightly shorter in length to trigonid ( $\text{tri:tal} \geq 0.92, < 1.27$ ); 3= talonid longer than trigonid ( $\text{tri:tal} < 0.91$ ).
140. p34. (Weight= 100). p4 anterobuccal cingulum development: 0= absent or trace; 1= strong.
141. p36.\* (Weight= 50). p4 postprotoconid ridge: 0= weak or absent; 1= present; 2= very strong.
142. p37.\* (Weight= 50). p4 postmetaconid ridge: 0= weak or absent; 1= moderate; 2= very strong.
143. p40.\* (Weight= 50). p4 paraconid height: 0= low; 1= moderate; 2= high (nearly as high as protoconid).
144. p41.\* (Weight= 50). p3-4 protoconid height: 0= p3 much lower than p4; 1= p3 equal or slightly lower than p4; 2= p3 higher than p4.
145. p42.\* (Weight= 25). Ratio of p3 to p4 area: 0= (0.45-0.59); 1= (0.60-0.69); 2= (0.70-0.79); 3= ( $> 0.80, \leq 1.10$ ); 4= ( $> 1.10$ ).
146. p43.\* (Weight= 20). p4 mesiodistal Length / buccolingual Width: 0= ( $< 0.95$ ); 1= ( $\geq 0.96, \leq 1.14$ ); 2= ( $\geq 1.15, < 1.20$ ); 3= ( $\geq 1.21, \leq 1.35$ ); 4= ( $\geq 1.36, \leq 1.46$ ); 5= ( $\geq 1.47$ ).
147. p44.\* (Weight= 20). p4 to m1 area: 0= ( $< 0.62$ ); 1= ( $\geq 0.63, \leq 0.72$ ); 2= ( $\geq 0.73, \leq 0.82$ ); 3= ( $\geq 0.83, \leq 0.92$ ); 4= ( $\geq 0.93, \leq 1.02$ ); 5= ( $\geq 1.03$ ).
148. p45. (Weight= 100). p3-4 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. [Score as missing if roots are singular].

### *Lower Molars*

149. m1. (Weight= 100). M3/m3: 0= present; 1= absent.
150. m2. (Weight= 100). m1 root number: 0= one; 1= two.
151. m3. (Weight= 100). m2 root number: 0= one; 1= two.
152. m4. (Weight= 100). m3 root number: 0= one; 1= two.
153. m6.\* (Weight= 50). m2 trigonid width (ratio of buccolingual breadths of trigonid and talonid): 0= much wider than talonid ( $\geq 1.11$ ); 1= widths similar ( $< 1.11, > 0.90$ ); 2= much narrower than talonid ( $\leq 0.90$ ).
154. m6a. (Weight= 100). m1 trigonid length: 0= m1 trigonid short on the lingual side; 1= m1 with elongate lingual face.
155. m7.\* (Weight= 50). 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 ( $< 1.05$ ).
156. m8.\* (Weight= 33). m1 paraconid position: 0= mesial to protoconid; 1= mesiolingual, between protoconid and metaconid; 2= mesial to metaconid but widely spaced from it; 3= twinned with metaconid.
157. m9.\* (Weight= 33). m2 paraconid position: 0= mesial to protoconid; 1= mesiolingual, between protoconid and metaconid; 2= mesial to metaconid but widely spaced from it; 3= twinned with metaconid.
158. m10.\* (Weight= 33). m3 paraconid position: 0= mesial to protoconid; 1= mesiolingual, between protoconid and metaconid; 2= mesial to metaconid but widely spaced from it; 3= twinned with metaconid.
159. m11. (Weight= 100). m1 parastylid: 0= absent; 1= present.
160. m12.\* (Weight= 50). Molar metastylid: 0= absent; 1= small; 2= large.
161. m13. (Weight= 100). m3 hypoconulid: 0= single; 1= double.
162. m14.\* (Weight= 50). m3 heel: 0= absent; 1= narrower than talonid; 2= approximately equal in width to talonid.

163. m15.\* (Weight= 50). Molar occlusal enamel surface: 0= smooth; 1= slightly crenulated; 2= highly crenulated.
164. m16.\* (Weight= 50). m1 trigonid height (ratio of trigonid height to talonid height): 0= trigonid higher than talonid ( $\geq 1.20$ ); 1= trigonid slightly higher than talonid ( $< 1.20, \geq 1.10$ ); 2= trigonid and talonid of similar height ( $< 1.10$ ).
165. m17.\* (Weight= 50). m1-2 cusp relief (ratio of hypoflexid height to hypoconid height, measured buccally): 0= low ( $< 1.20$ ); 1= moderate ( $\geq 1.20, < 1.35$ ); 2= high ( $> 1.35$ ).
166. m18. (Weight= 100). m1 trigonid lingual configuration: 0= open; 1= closed.
167. m19. (Weight= 100). m1 metaconid position: 0= lingual to protoconid; 1= slightly distolingual to protoconid.
168. m20.\* (Weight= 50). m1-2 paraconid development: 0= absent; 1= small; 2= large.
169. m21. (Weight= 100). m1-2 lateral protocristid orientation: 0= runs toward metaconid; 1= runs toward hypoflexid.
170. m22. (Weight= 100). 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 discerned.
171. m23. (Weight= 100). m2 distal trigonid wall: 0= complete; 1= deeply notched by a sulcus between protoconid and metaconid; 2= medial and lateral protocristid do not meet but no sulcus is present.
172. m24a. (Weight= 100). m1 wear facet X: 0= present; 1= absent.
173. m24b. (Weight= 100). m2 wear facet X: 0= present; 1= absent.
174. m25.\* (Weight= 50). m1-2 entoconid: 0= absent or very low, 1= lower than metaconid; 2= large.
175. m26.\* (Weight= 50). m1-2 postentoconid sulcus: 0= prominent; 1= shallow sulcus; 2= absent.
176. m27.\* (Weight= 33). m1 hypoconulid size: 0= large; 1= moderate; 2= small; 3= absent.

177. m28\* (Weight= 33). m2 hypoconulid size: 0= large; 1= moderate; 2= small; 3= absent.
178. m29.\* (Weight= 33). m3 hypoconulid size: 0= large; 1= moderate; 2= small; 3= absent.
179. m30.\* (Weight= 50). m1-2 hypoconulid position: 0= twinned to entoconid; 1= near midline; 2= slightly buccal to midline.
180. m31.\* (Weight= 50). m1-2 cristid obliqua development: 0= weak (rounded); 1= strong (trenchant); 2= very strong (very trenchant).
181. m32.\* (Weight= 50). 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.
182. m33.\* (Weight= 50). 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.
183. m34. (Weight= 100). 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.
184. m35. (Weight= 100). 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.
185. m36. (Weight= 100). 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.
186. m37. (Weight= 100). m1-2 centroconid development: 0= present; 1= absent.
187. m38.\* (Weight= 50). m1-2 hypocristid development: 0= absent or seen only as a trace; 1= weak; 2= strong.
188. m39.\* (Weight= 50). m3 hypocristid development: 0= absent or seen only as a trace; 1= weak; 2= strong.

189. m40.\* (Weight= 50). m1-2 talonid, lingual configuration: 0= open; 1= closed, notched lingually; 2= closed, no notch.
190. m41. (Weight= 100). m1-2 distal fovea: 0= absent; 1= present.
191. m44. (Weight= 100). Molar cusp inflation: 0= cusps not inflated, marginally positioned; 1= very inflated.
192. m45.\* (Weight= 50). m1-2 buccal cingulum development: 0= absent to trace; 1= partial, broken at protoconid and hypoconid; 2= complete.
193. m46.\* (Weight= 50). m1 hypoflexid depth: 0= very shallow; 1= moderate; 2= deep.
194. m47.\* (Weight= 50). m2 hypoflexid depth: 0= very shallow; 1= moderate; 2= deep.
195. m53.\* (Weight= 25). Ratio of m2 length to m3 length: 0= m3 much longer than m2 (0.71-0.80); 1= m3 longer than m2 (0.81-0.90); 2= m3 equal to m2 (0.91-1.00); 3= m3 smaller than m2 (1.01-1.12); 4= m3 much smaller than m2 ( $\geq 1.13$ ). Score as "5" if m3 absent.
196. m54.\* (Weight= 33). m1 length: 0= (< 2.5 mm); 1= ( $\geq 2.5$ , < 3.8 mm); 2= ( $\geq 3.8$ ,  $\leq 6.0$  mm); 3= (> 6.0 mm).
197. m55.\* (Weight= 33). m1 L/W: 0= (1.0-1.15); 1= (1.16-1.22); 2= (1.23-1.32); 3= (> 1.33).
198. m57. (Weight= 100). m1-2 entoconid position relative to hypoconid: 0= transverse to hypoconid; 1= distal to hypoconid.

#### *Upper Incisors*

199. I1.\* (Weight= 50). I1-I2 interstitial contact: 0= absent, teeth widely spaced; 1= present as narrow contact; 2= I2 tightly packed against I1, with I1 preparacrista abbreviated.
200. I2. (Weight= 100). I1-I1 interstitial contact: 0= present; 1= absent: a wide space occurs in the midline between these teeth.
201. I3. (Weight= 100). I2-C1 diastema: 0= present; 1= absent.

202. I4.\* (Weight= 50). Ratio of I1 area to I2 area: 0= areas approximately equal ( $\leq 1.00$ ); 1= I1 slightly larger than I2 ( $> 1.00, < 1.40$ ); 2= I1 much larger than I2 ( $\geq 1.40$ ).
203. I5.\* (Weight= 50). I1 size (I1 area: M1 area): 0= small ( $\leq 0.50$ ); 1= moderate ( $> 0.50, < 0.56$ ); 2= large ( $\geq 0.56$ ).
204. I6.\* (Weight= 50). I1 occlusal shape (mesiodistal length / buccolingual breadth): 0= rounded oval ( $< 1.05$ ); 1= buccolingually compressed ( $\geq 1.05, \leq 1.30$ ); 2= extremely compressed ( $> 1.30$ ).
205. I7.\* (Weight= 50). I2 occlusal shape (mesiodistal length / buccolingual breadth): 0= rounded oval ( $\leq 1.05$ ); 1= slightly compressed ( $> 1.05, < 1.30$ ); 2= extremely compressed ( $\geq 1.30$ ).
206. I8.\* (Weight= 50). I1 crown shape: 0= spatulate; no apparent occlusal cusp, mesial and distal edges continuous and rounded; 1= semi-spatulate, central cusp present but blunt with discernable mesial and distal occlusal crests; 2= central occlusal cusp pointed, occlusal edges steep.
207. I9. (Weight= 100). I1 lingual fovea: 0= simple; 1= dual with mid-crown pillar.
208. I10. (Weight= 100). I1 occlusal edge orientation (spatulate incisors only): 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.
209. I11.\* (Weight= 50). I1-2 lingual cingulum: 0= weak, discontinuous; 1= narrow, continuous; 2= strong.
210. I12. (Weight= 100). I1 basal lingual cusp: 0= absent; 1= present.
211. I13. (Weight= 100). I1 and I2 buccal cingulum: 0= absent; 1= present.

### *Upper canines*

212. C1. (Weight= 100). C1 cross-sectional shape (ratio of maximum length in the occlusal plane to maximum breadth in the occlusal plane at right angles to maximum length): 0= oval ( $\geq 1.16$ ); 1= rounded ( $< 1.16$ ).

213. C2. (Weight= 100). Upper canine occlusion: 0= C1 wears against P1-2; 1= C1 wears against P2; 2= C1 wears against P2-3; 3= C1 wears against P3.
214. C3. (Weight= 100). C1 mesial groove (females): 0= shallow or absent; 1= deep.
215. C4.\* (Weight= 50). C1 lingual cingulum: 0= weak or absent; 1= strong; 2= very strong.

### *Upper premolars*

216. P1.\* (Weight= 50). P2 root number: 0= one; 1= two; 2= three. If tooth is absent, character scored as "9".
217. P2.\* (Weight= 50). P3 root number: 0= one; 1= two; 2= three.
218. P3.\* (Weight= 50). P4 root number: 0= one; 1= two; 2= three.
219. P4.\* (Weight= 50). Ratio of P2 area to P3 area: 0= P2 very small ( $\leq 0.85$ ); 1= P2 small ( $> 0.85, < 0.95$ ); 2= P2 equal ( $\geq 0.95$ ). If tooth is absent, character scored "9".
220. P5.\* (Weight= 33). Ratio of P4 area to M1 area: 0= P4  $\ll$  M1 ( $\leq 0.66$ ); 1= P4 < M1 (0.67-0.76); 2= P4 = M1 (0.77-1.05); 3= P4 > M1 ( $> 1.06$ ).
221. P6.\* (Weight= 50). P2 occlusal shape (mesiodistal length/buccolingual breadth): 0= buccolingually broad ( $\leq 0.80$ ); 1= round ( $> 0.80, \leq 1.05$ ); 2= mesiodistally elongate ( $> 1.05$ ).
222. P8. (Weight= 100). P3-4 trigon/talon proportions: 0= trigon and talon proportions similar; 1= trigon much shorter than talon with the protocone situated on the mesial aspect of the crown.
223. P9. (Weight= 100). P3 protocone: 0= present; 1= absent.
224. P10. (Weight= 100). P4 metacone: 0= absent; 1= present.
225. P11. (Weight= 100). P4 protocone: 0= low relative to paracone; 1= high relative to paracone.
226. P12. (Weight= 100). P2 protocone: 0= present as discrete cusp; 1= absent or indistinguishable from lingual cingular ridge.

227. P13a.\* (Weight= 33). Premolar hypocones: 0= absent; 1= present on P4 only; 2= present on P3-4; 3= present on P2-4.
228. P13b.\* (Weight= 50). P4 hypocone: 0= absent or trace; 1= bump on postprotocone crista or postcingulum; 2= distinct cusp on distal margin.
229. P14.\* (Weight= 50). P4 paraconule: 0= large; 1= small; 2= absent.
230. P15. (Weight= 100). P3-4 parastyles: 0= present; 1= weak or absent.
231. P16. (Weight= 100). P3-4 metastyles: 0= weak or absent; 1= present.
232. P17. (Weight= 100). P3-4 postprotocrista: 0=strong, reaches the distal margin and joins the postcingulum; 1= weak, short.
233. P18. (Weight= 100). P2-3 profile of distal crown margin: 0= convex, smoothly rounded; 1= concave, "waisted" between buccal and lingual cusps.
234. P19. (Weight= 100). P3-4 lingual cingulum: 0= absent or weak; 1= strong.
236. P21. (Weight= 100). P3-4 buccal cingulum: 0= absent or weak; 1= strong.

#### *Upper molars*

237. M1.\* (Weight= 50). M1-2 root count: 0= three, three; 1= three, two; 2= two, two.
238. M2.\* (Weight= 50). M3 root count: 0= three; 1= two; 2= one.
239. M3.\* (Weight= 50). M2 shape (ratio of buccolingual breadth / mesiodistal length): 0= very transverse ( $> 1.65$ ); 1= transverse ( $\leq 1.65, > 1.30$ ); 2= squared ( $\leq 1.30$ ).
240. M4.\* (Weight= 50). Ratio of M1 area to M2 area: 0=  $M1 \gg M2 (\geq 1.40)$ ; 1=  $M1 > M2 (< 1.40, > 1.0)$ ; 2=  $M1 \leq M2 (\leq 1.0)$ .
241. M5.\* (Weight= 50). M1-2 Nannopithec-fold: 0= absent; 1= weak; 2= strong.
242. M6.\* (Weight= 50). M1-2 pseudohypocone: 0= absent; 1= small; 2= large.
243. M7. (Weight= 100). M1-2 metaconule: 0= single (or absent); 1= double.
244. M8.\* (Weight= 50). M1-2 paraconule: 0= absent; 1= small; 2= large.
245. M9.\* (Weight= 50). M1-2 preprotoconule crista: 0= absent; 1= weak; 2= strong.
246. M10.\* (Weight= 50). M1 hypocone size: 0= large; 1= small; 2= absent.
247. M11.\* (Weight= 50). M2 hypocone size: 0= large; 1= small; 2= absent.

- ~~248. M12. (Weight= 100). M1-2 hypocone position: 0= distal, slightly lingual to protocone; 1= distal, far lingual to protocone. (see Character 400).~~
249. M13a.\* (Weight= 50). M1-2 prehypocrista: 0= absent; 1= weak; 2= strong, reaches to the postprotocrista, encloses the talon lingually.
250. M13b. (Weight= 100). M1-2 prehypocrista orientation: 0= buccolingually towards postprotocrista; 1= buccally towards metaconule.
251. M14.\* (Weight= 50). M3 prehypocrista development: 0= absent; 1= weak; 2= strong, reaches to postprotocrista to enclose the talon lingually.
252. M15. (Weight= 100). M1 or M2 paraconule position: 0= attached to preprotocrista; 1= not attached to preprotocrista.
- ~~253. M16.\* (Weight= 50). M1-2 metaconule size: 0= absent; 1= small to moderate; 2= large. (see Character 401).~~
- ~~254. M17. (Weight= 100). M1-2 mesostyle size: 0= absent; 1= present, attached to ectocrista; 2= present on buccal cingulum. (see Character 402-403).~~
- ~~255. M18. (Weight= 100). M1-2 postprotocrista: 0= strong, runs to base of metaconule or metacone; 1= strong but short; does not reach base of metacone; 2= absent. (see Character 404-410).~~
- ~~256. M18A. (Weight=100). M1-2 postprotocrista spur: 0= postprotocrista splits with a spur running distally towards the hypocone (if present); 1: spur absent.~~
- Comments: This is a new character not found in Kay et al. 2004. **(Deleted)**
- ~~257. M19. (Weight= 100). M1-2 lateral posterior transverse crista: 0= sharp; 1= indistinct. (see Character 411-413).~~
258. M20.\* (Weight= 50). P4-M1-2 pericone: 0= absent; 1= small; 2= large.
- ~~259. M22.\* (Weight= 50). M1-3 lingual cingulum development: 0= absent; 1= weak, broken; 2= strong, complete. (see Character 414-415).~~
260. M24.\* (Weight= 50). M1-2 buccal cingulum development: 0= absent; 1= weak; 2= strong.
261. M27. (Weight= 100). M1-2 premetaconule cristae: 0= absent or weak; 1= strong.
262. M28. (Weight= 100). M1-2 postmetaconule cristae: 0= absent or weak; 1= strong.

263. M30.\* (Weight= 50). M3 paracone: 0= absent; 1= small-moderate; 2= large.
264. M31.\* (Weight= 50). Molar protocone lingual inflation: 0= not inflated; 1= slightly inflated; 2= very inflated.
265. M33. (Weight= 100). M2 buccal expansion of paracone: 0= no expansion; 1= expanded.
266. M34.\* (Weight= 50). M3 metacone: 0= absent or very small; 1= moderate (but smaller than paracone); 2= large (equal to paracone).
267. M36.\* (Weight= 50). M3 hypocone: 0= absent or very small; 1= small; 2= large.
- ~~268. M44.\* (Weight= 50). M1-3 anterior cingulum: 0= strong, complete, long; 1= strong, short; 2= weak or absent. (see Character 423-424).~~
269. M46.\* (Weight= 50). M1 size relative to M3 (based on the ratio of areas of each tooth): 0=  $M1 \geq 2.5$  times the size of M3 (scored as "0" when M3 is absent); 1=  $M1 < 2.5$ ,  $\geq 1.5$  times M3; 2=  $M1 < 1.5$  times M3.

### Humeral characters

270. H1 of Ross et al. (1998)\*. (Weight= 50). Shape of humeral trochlea: 0= cylindrical, distal edge perpendicular to humeral shaft; 1= slightly conical, distal edge slightly angled to shaft; 2= conical, distal edge steeply angled to humeral shaft.
271. H2 of Ross et al. (1998). (Weight= 100). Relative heights of medial and lateral edges of humeral trochlea: 0= subequal—spool-shaped; see below; 1= medial flared relative to lateral.
272. H3 of Ross et al. (1998)\*. (Weight= 33). Trochleocapitular ridge: 0= absent; 1= slightly distinct; 2= moderately distinct; 3= very distinct.
273. H4 of Ross et al. (1998). (Weight= 100). Waisting of the trochlea: Minimum trochlear diameter (MinTD) / Maximum trochlear diameter (MaxTD), expressed as a percentage (Ford, 1994): 0= unwaisted ( $> 70$ ); 1= waisted ( $\leq 70$ ).

274. H5 of Ross et al. (1998)\*. (Weight= 33). Width of capitulum relative to trochlea: Ventral capitulum width / ventral trochlear width expressed as a percentage (Ford, 1994): 0= (< 100); 1= ( $\geq 100$ , < 140); 2= ( $\geq 140$ ,  $\leq 200$ ); 3= > 200.
275. H6 of Ross et al. (1998)\*. (Weight= 50). Entepicondylar foramen (Ford, 1986): 0= present; 1= variable; 2= absent.
276. H7 of Ross et al. (1998). (Weight= 100). Entepicondylar foramen position (Ford, 1986): 0= over medial epicondyle; 1= above ventral trochlea; 2= above dorsal trochlea; 3= absent.
277. H8 of Ross et al. (1998). (Weight= 100). Medial epicondyle size (Fleagle and Kay, 1987): 0= small; 1= prominent.
278. H9 of Ross et al. (1998)\*. (Weight= 50). Dorsal position of medial epicondyle (Ford, 1994): 0= parallel; 1= slight dorsal angle; 2= large dorsal angle.
279. H10 of Ross et al. (1998). (Weight= 100). Shape of dorsal trochlea (Fleagle and Simons, 1995): 0= no pronounced lips on dorsal trochlear edges; 1= both medial and lateral edges pronounced; 2= very pronounced lateral lip.
280. H11 of Ross et al. (1998)\*. (Weight= 50). Dorso-epitrochlear fossa (Fleagle and Simons, 1995): 0= present, strong; 1= small, shallow; 2= absent.
281. H12 of Ross et al. (1998)\*. (Weight= 50). Olecranon fossa shape (Fleagle and Simons, 1995): 0= shallow; 1= moderate; 2= deep.
282. H13 of Ross et al. (1998). (Weight= 100). Supinator crest (Fleagle and Kay, 1987): 0= prominent (extends far proximally); 1= low (terminates close to the distal end of the bone).
283. H14 of Ross et al. (1998)\*. (Weight= 50). Brachialis flange: 0= broad; 1= moderate; 2= narrow.
284. H15 of Ross et al. (1998). (Weight= 100). Bicipital groove (Fleagle and Kay, 1987): 0= shallow; 1= deep.
285. H16 of Ross et al. (1998). (Weight= 100). Deltopectoral crest (Ford, 1980a; Fleagle and Kay, 1987): 0= prominent; 1= low (rounded and indistinct edge, especially proximally); 2= flattened superiorly.

286. H17 of Ross et al. (1998). (Weight= 100). Deltotriceps crest (Fleagle and Kay, 1987): 0= low; 1= prominent.
287. Medial torsion of humeral head (Weight= 100) (Evans and Krahl, 1945; Napier and Davis, 1959; Harrison, 1987). Rotation: 0= not medially rotated; 1= medially rotated.

### Wrist characters

288. W1 of Ross et al. (1998). (Weight= 100). Os Centrale (Napier and Davis, 1959; Schön and Ziemer, 1973; Ross et al., 1998): 0= small; 1= large.
289. W2 of Ross et al. (1998). (Weight= 100). Ulnar-pisiform articulation (Lewis, 1971; Ross et al., 1998): 0= pisiform facet = triq; 1= pisiform facet enlarged.

### Femoral characters

290. F1 of Ross et al. (1998)\*. (Weight= 50). Length of femoral neck (neck length measurement number 2/BSTD expressed as a percentage; Dagosto et al., 1995; Dagosto and Schmid, 1996): 0= short (< 75); 1= moderate (75–120); 2= long (> 120).
291. F2 of Ross et al. (1998)\*. (Weight= 50). Angle of femoral neck (Dagosto et al., 1995): 0= (< 60°); 1= (60°–70°); 2= (> 70°).
292. F3 of Ross et al. (1998). (Weight= 100). Angle of lesser trochanter LTA (Dagosto and Gebo, 1994; Dagosto and Schmid, 1996): 0= medial (0–30°); 1= posterior (> 30°).
293. F4 of Ross et al. (1998)\*. (Weight= 50). Size of third trochanter (Dagosto and Gebo, 1994): 0= large (third trochanter projection index: > 25); 1= moderate (third trochanter projection index: > 10, ≤ 25); 2= crestiform or absent.
294. F5 of Ross et al. (1998)\*. (Weight= 33). Knee shape (anteroposterior diameter of distal femur / mediolateral diameter of distal femur, expressed as a percentage; Dagosto and Gebo, 1994): 0= (> 107); 1= (107-99); 2= (< 99, ≥ 71); 3= (< 71).

295. F6 of Ross et al. (1998)\*. (Weight= 50). Femoral head shape (Dagosto and Gebo, 1994): 0= spherical; 1= semicylindrical; 2= cylindrical.
296. F7 of Ross et al. (1998). (Weight= 100). Anterior extension of greater trochanter (Dagosto and Gebo, 1994): 0= no extension; 1= extension.
297. F8 of Ross et al. (1998)\*. (Weight= 50). Anterior bowing of proximal femur (Ford, 1986; Dagosto and Gebo, 1994): 0= straight; 1= slightly bowed; 2= pronounced bowing.
298. F9 of Ross et al. (1998)\*. (Weight= 50). Relative length of trochanteric fossa (intertrochanteric fossa length/BSDLT), expressed as a percentage (Dagosto and Schmid, 1996): 0= long (> 125); 1= moderate (110–125); 2= very short (< 110).
299. F10 of Ross et al. (1998). (Weight= 100). Intertrochanteric crest (Dagosto and Gebo, 1994): 0= crest absent; 1= crest present.
300. F11 of Ross et al. (1998)\*. (Weight= 50). Size of lesser trochanter (Dagosto, 1990): 0= large; 1= intermediate; 2= small.
301. F12 of Ross et al. (1998). (Weight= 100). Lateral border of distal femur (i.e., the lateral rim of the patellar groove; Dagosto, 1990): 0= low; 1= high.
302. Crista paratrochanterica\*. (Weight= 50). Crista paratrochanterica on posterior femoral neck (HersHKovitz, 1988): 0= flat; 1= low ridge or cusp; 2= high ridge.
303. Femoral head projection\*. (Weight= 50). Projection of the femoral head relative to the greater trochanter: 0= greater trochanter projects well above the femoral head; 1= greater trochanter is at the same level as the femoral head; 2= greater trochanter well below (distal to) the femoral head.

### Limb indices

304. Intermembral index\*. (Weight= 50). Sum of lengths of humerus and radius divided by summed lengths of femur plus tibia expressed as a percentage: 0= long hindlimb ( $\leq 72$ ); 1= moderate hindlimb ( $\geq 73, \leq 85$ ); 2= short hindlimb ( $\geq 86$ ).

305. Humerofemoral index\*. (Weight= 50). Ratio of humerus length to femur length expressed as a percentage: 0= ( $\leq 65$ ); 1= ( $\geq 66, \leq 82$ ); 2= ( $\geq 83$ ).

### **Tibial characters**

306. T1 of Ross et al. (1998)\*. (Weight= 33). Contact between distal tibia and fibula (Dagosto and Gebo, 1994, p. 570): 0= absent; 1= small facet; 2= extensive facet; 3= proximal fusion (synostosis).

307. T3 of Ross et al. (1998). (Weight= 100). Distal tibia articulation shape: 0= square; 1= triangular.

308. T3a\*. (Weight= 50). Shape of distal tibial articular for talus, if 'square': 0= narrow articular surface (width to breadth ratio  $< 100$ ); 1= wider articular surface width to breadth ( $\geq 100, < 130$ ); 2= wide articular surface ( $> 130$ ).

309. T4 of Ross et al. (1998)\*. (Weight= 50). Medial malleolus rotation: 0= none; 1= slight; 2= strong.

310. T5 of Ross et al. (1998)\*. (Weight= 50). Medial malleolar articulation: 0= flat; 1= anteriorly convex; 2= all convex.

311. T6 of Ross et al. (1998). (Weight= 100). Shape distal tibia shaft: 0= no compression; 1= anteroposteriorly compressed.

312. T7 of Ross et al. (1998). (Weight= 100). Tibialis posterior groove: 0= variably distinct, on the lateral side of the medial malleolus; 1= medial to a raised crest on the posterior side of malleolus.

313. Talar trochlea\*. (Weight= 50). Posterior border of the trochlear facet for talus: 0= flat; 1= rounded; 2= sharp.

314. Tibial malleolar height\*. (Weight= 50). Medial malleolar height of the tibia relative to the anteroposterior diameter of distal tibial shaft, expressed as a percentage: 0= ( $\leq 68$ ); 1= ( $> 68, \leq 101$ ); 2= ( $> 101$ ).

### Astragalar (talar) characters

315. A1 of Ross et al. (1998). (Weight= 100). Position of the groove for the tendon of m. flexor fibularis longus: 0= lateral to the posterior part of the tibiotalar joint; 1= groove is plantar and central to the facet.
316. A2 of Ross et al. (1998)\*. (Weight= 50). Shape of talofibular facet: 0= steep-sided; 1= steep-sided with a plantar lip; 2= sloped obliquely.
317. A3 of Ross et al. (1998). (Weight= 100). Length of the talar-tibial articulation: 0= dorsoventrally deep, extends to plantar aspect of talus; 1= dorsoventrally restricted, confined to dorsal part of talus.
318. A4 of Ross et al. (1998). (Weight= 100). Size of the posterior trochlear shelf of talus: 0= absent or weakly developed; 1= well-developed (prominent).
319. A5'\*. (Weight= 50). Talar neck length (neck length / talus length) expressed as a percentage: 0= short ( $\leq 44$ ); 1= moderate ( $\geq 45, \leq 56$ ); 2= long ( $> 56$ ).
320. A7 of Ross et al. (1998). (Weight= 100). Symmetry of the lateral versus medial talar trochlea: 0= trochlea symmetric; 1= lateral trochlear rim is raised relative to medial trochlear rim.
321. A8 of Ross et al. (1998). (Weight= 100). Talar cotylar fossa: 0= shallow; 1= deep, medially projecting.
322. A9'\*. (Weight= 50). Width of talar head (Head width / Head height, expressed as a percentage): 0= ( $< 115$ ); 1= (115-127); 2= ( $> 127$ ).
323. A10\* of Ross et al. (1998). (Weight= 50). Talar neck angle: 0= ( $< 20^\circ$ ); 1= ( $20-30^\circ$ ); 2= ( $> 30^\circ$ ).
324. A11\* of Ross et al. (1998). (Weight= 50). Talar body height (lateral body height/midtrochlear width) expressed as a percentage: 0= ( $< 100$ ); 1= (100-120); 2= ( $> 120$ ).
325. A12 of Ross et al. (1998). (Weight= 100). Talar shape (Talar width/Talar length) expressed as a percentage: 0= ( $\leq 60$ ); 1= ( $> 60$ ).

## Calcaneal characters

326. C1 of Ross et al. (1998)\*. (Weight= 50). Anterior calcaneal elongation. Length of calcaneus distal to talo–calcaneal facet/total calcaneal length expressed as a percentage: 0= not elongate (< 40); 1= moderately elongate (40-45); 2= long (> 45).
327. C3 of Ross et al. (1998). (Weight= 100). Posterior calcaneal bowing: 0= absent; 1= present.
328. Calcaneal peroneal tubercle\*. (Weight= 20). Presence and location of peroneal tubercle: 0= absent; 1= located at the far anterior end of bone; 2= in the anterior half; 3= centered; 4= in the posterior half.
329. Calcaneal sustentacular facet\*. (Weight= 50). Presence of a connection between anterior and medial sustentacular facets of the calcaneus: 0= facets separate; 1= sharply angled to one another or do not connect everywhere; 2= facets broadly confluent.
330. Angle of posterior talar facet (of calcaneus)\*. (Weight= 33). 0= (< 3°); 1= (3-8°); 2= (> 8°, ≤ 24°); 3= (> 24°).
331. Length of posterior articular facet (of calcaneus)\*. (Weight= 50). Ratio of posterior articular facet length to maximum length of cuboid articular surface (PASL/L) (Ford, 1980b): 0= (< 90); 1= (90-110); 2= (111-128); 3= (> 128).
332. Breadth of posterior articular facet (of calcaneus). (Weight= 100). Ratio of posterior articular facet width (PASW) to maximum length of the cuboid articular surface, expressed as a percentage: 0= (< 70); 1= (> 70).
333. Anterior calcaneal length\*. (Weight= 20). The ratio of the length of anterior calcaneus to the maximum calcaneal length, expressed as a percentage: 0= (≤ 28); 1= (> 28, ≤ 33); 2= (> 33, ≤ 48); 3= (> 48, ≤ 60); 4= (> 60).
334. Shape of posterior articular facet (on calcaneus)\*. (Weight= 50). Ratio of the width to length of the posterior articular facet for talus, expressed as percentage: 0= (< 42); 1= (42-76); 2= (> 76).

335. Posterior calcaneus length\*. (Weight= 50). Length of posterior calcaneus relative to maximum length of cuboid articular surface expressed as a percentage: 0= (< 61); 1= (61-107); 2= (> 107).

### Navicular characters<sup>1</sup>

336. N1\* of Ross et al. (1998). (Weight= 50). Navicular shape. Length relative to width of the navicular, expressed as a percentage: 0= short (< 90); 1= moderate (100-150); 2= long (> 150).

337. N3 of Ross et al. (1998). (Weight= 100). Naviculocuboid articulation. The naviculocuboid articulation: 0= cuboid facet on navicular contacts only the ectocuneiform; 1= cuboid facet contacts the ectocuneiform and mesocuneiform facet.

### Entocuneiform characters

338. E1\* of Ross et al. (1998). (Weight= 50). Shape of entocuneiform/first metatarsal articulation: 0= dorsally reduced; 1= dorsal moiety of joint enlarged relative to ventral moiety; 2= dorsal moiety greatly enlarged.

339. E2 of Ross et al. (1998). (Weight= 100). Lateral process of the entocuneiform: 0= small; 1= hypertrophied.

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<sup>1</sup> For the most part the data for the navicular, entocuneiform, and entocuneiform are restricted to *Aotus*, *Callicebus* and *Saimiri*, based on Kay et al. (2004). Other taxa not examined.

### General foot characters

340. O1 of Ross et al. (1998)\*. (Weight= 50). Foot axis: 0= mesaxonic; 1= paraxonic; 2= ectaxonic.
341. O2 of Ross et al. (1998). (Weight= 100). Toilet claw (first phalanx, hind foot): 0= absent; 1= present.
342. External thumb: (Weight= 100). 0= present; 1= reduced or absent.
343. O3 of Ross et al. (1998). (Weight= 100). Prehallux: 0= present; 1= absent.
344. O4. Metatarsus length. (Weight= 100): 0= short; 1= long.

### Metatarsal characters

345. MT1\* of Ross et al. (1998)\*. (Weight= 50). Peroneal tubercle of the first metatarsal: 0= very large; 1= large; 2= small.
346. MT2 of Ross et al. (1998). (Weight= 100). Hallux length: 0= short; 1= long.

### Other postcranial and miscellaneous characters

347. Claws (hand). (Weight= 100): 0= absent; 1= present.
348. Lumbar vertebrae count. (Weight= 100). Number of lumbar vertebrae: 0= (> 5); 1= ( $\leq 5$ ).
349. Tail length\*. (Weight= 50). Ratio of tail length to head and body length, expressed as a percentage: 0= short (TL:HB < 73); 1= moderate (73-116); 2= long (> 116).
350. Glabrous skin on tail. (Weight= 100). Friction pads on the tail: 0= absent; 1= present.
351. Baculum: (Weight= 100). 0= absent: 1= present.
352. Scent glands on genitalia (Weight= 100): 0= present; 1= absent.

## Lower deciduous tooth characters

All character numbers from Kay and Meldrum (1997). For terminology consult Kay (1978, 1980).

- 353. dp1. (Weight= 100): dp2-3 root numbers: 0= single; 1= double.
- 354. dp2a\*. (Weight= 50). dp2 trigonid to talonid proportions: 0= dp2 trigonid >> talonid; 1= dp2 trigonid slightly longer than talonid; 2= dp2 trigonid and talonid of similar length.
- 355. dp3b\*. (Weight= 50). dp3 trigonid to talonid proportions: 0= dp3 trigonid >> talonid; 1= dp3 trigonid slightly longer than talonid; 2= dp3 trigonid and talonid of similar length.
- 356. dp4. (Weight= 100). dp2 protoconid projection: 0= protoconid slender, projecting; 1= protoconid robust, projecting; 2= protoconid does not project above dp3-4.
- 357. dp5a. (Weight= 100). dp2 metaconid: 0= metaconid close to protoconid; 1= metaconid widely spaced from protoconid.
- 358. dp5b. (Weight= 100). dp3 metaconid: 0= metaconid close to protoconid; 1= metaconid widely spaced from protoconid.
- 359. dp6a\*. (Weight= 50). dp2 metaconid: 0= absent; 1= trace or small; 2= large.
- 360. dp6b\*. (Weight= 50). dp3 metaconid: 0= absent; 1= trace or small; 2= large.
- 361. dp8a. (Weight= 100). dp2 trigonid: 0= closed lingually; 1= open lingually.
- 362. dp8b. (Weight= 100). dp3 trigonid: 0= closed lingually; 1= open lingually.
- 363. dp11a\*. (Weight= 50). dp2 entoconid: 0= absent; 1= present but cristiform; 2= present as discrete cusp.
- 364. dp11b\*. (Weight= 50). dp3 entoconid: 0= absent; 1= present but cristiform; 2= present as discrete cusp.
- 365. dp14a. (Weight= 100). dp2 lateral and medial protocristids: 0= confluent; 1= separate.

366. dp14b. (Weight= 100). dp3 lateral and medial protocristids: 0= confluent; 1= separate.
367. dp15a. (Weight= 100). dp2 metaconid position: 0= metaconid lingual or slightly distal to protoconid; 1= metaconid far distal to protoconid.
368. dp15b. (Weight= 100). dp3 metaconid position (or orientation of postmetacristid): 0= metaconid lingual or slightly distal to protoconid; 1= metaconid far distal to protoconid.
369. dp18a\*. (Weight= 50). dp2 hypoconid size: 0= large; 1= small; 2= absent.
370. dp18b\*. (Weight= 50). dp3 hypoconid size: 0= large; 1= small; 2= absent.
371. dp19\*. (Weight= 50). dp3 hypoconid position: 0= hypoconid distal to protoconid; 1= intermediate; 2= hypoconid distal to metaconid.
372. dp21\*. (Weight= 50). dp3 hypocristid: 0= absent; 1= weak; 2= small.
373. dp22\*. (Weight= 50). dp2-3 buccal cingulum: 0= absent; 1= incomplete; 2= complete.
374. dp23\*. (Weight= 50). dp2 shape: 0= buccolingually compressed; 1= rounded oval; 2= buccolingually broad.
375. dp24. (Weight= 100). dp4 roots: 0= one root; 1= two roots.
376. dp25. (Weight= 100). dp4 cusp relief: 0= moderate to high relief; 1= low relief.
377. dp26\*. (Weight= 50). dp4 trigonid to talonid width: 0= wide (trigonid mesiodistal  $\geq$  1.1 talonid mesiodistal length); 1= widths similar ( $< 1.1$ ,  $> 0.95$ ); 2= narrow ( $\leq 0.95$ ).
378. dp27. (Weight= 100). dp4 trigonid: 0= open lingually; 1= closed lingually.
379. dp28. (Weight= 100). dp4 metaconid position: 0= lingual or slightly distal to protoconid; 1= far distal to protoconid.
380. dp29\*. (Weight= 50). dp4 paraconid: 0= absent or cristiform; 1= small discrete cusp; 2= large cusp.
381. dp30\*. (Weight= 50). dp4 lateral protocristid: 0= runs towards metaconid; 1= runs toward hypoflexid; 2= absent.
382. dp31. (Weight= 100). dp4 posterior trigonid wall: 0= complete; 1= sulcus between lateral and medial protocristids.

383. dp32. (Weight= 100). dp4 facet X: 0= present; 1= absent.
384. dp33\*. (Weight= 33). dp4 entoconid: 0= absent; 1= cristiform; 2= small discrete cusp; 3= large.
385. dp34. (Weight= 100). dp4 postentoconid sulcus: 0= present; 1= absent.
386. dp35\*. (Weight= 50). dp4 hypoconulid: 0= large; 1= moderate; 2= trace or absent.
387. dp36\*. (Weight= 50). dp4 hypoconulid: 0= twinned to entoconid; 1= slightly lingual to midline; 2= in midline.
388. dp37\*. (Weight= 50). dp4 cristid obliqua: 0= absent; 1= rounded; 2= trenchant.
389. dp38\*. (Weight= 50). dp4 cristid obliqua orientation: 0= towards protoconid; 1= between protoconid and metaconid; 2= towards metaconid.
390. dp39\*. (Weight= 50). dp4 cristid obliqua terminus: 0= to base of trigonid; 1= partway up trigonid; 2= to protoconid or protocristid.
391. dp40. (Weight= 100). dp4 centroconid: 0= present; 1= absent.
392. dp41\*. (Weight= 50). dp4 hypocristid: 0= absent; 1= weak; 2= strong.
393. dp42\*. (Weight= 50). dp4 buccal cingulum: 0= absent; 1= partial, broken; 2= complete.
394. dp43\*. (Weight= 100). dp4 talonid: 0= open lingually; 1= closed lingually.
395. dp44. (Weight= 50). dp4 hypoflexid: 0= very shallow; 1= shallow; 2= deep.
396. dp45. (Weight= 100). dp4 distal fovea: 0= absent; 1= present.
397. dp46. (Weight= 100). dp4 hypocristid accessory cusp: 0= absent; 1= present.
398. dp47. (Weight= 100). dp4 cristid obliqua: 0= straight; 1= notched.
399. dp48. (Weight= 100). dp4 trigonid mesiodistal proportions: 0= elongate relative to talonid; 1= short relative to talonid.

### Re-interpreted and added upper molar characters

(From Marivaux et al., 2005, 2013 and Marivaux, 2006)

400. ML-175. M12'\* . (Weight= 33). M1-2 hypocone position: 0= distal, far lingual to protocone; 1= distal, slightly lingual to protocone; 2= same level (mesiodistally opposed); 3= distal, slightly buccal to protocone.
401. ML-179. M16\* . (Weight= 33). M1-2 metaconule: 0= absent to indistinct; 1= small; 2= moderate; 3= large.
402. ML-181. M17'\* . (Weight= 50). M1-2 mesostyle size: 0= absent to indistinct; 1= moderate; 2= strong.
403. ML-182. M17'' . (Weight= 100). M1-2 mesostyle position: 0= attached to ectocrista; 1= present on buccal cingulum.
404. ML-207. ML156. (Weight= 100). M1-2 postprotocrista development: 0= strong; 1= tiny.
405. ML-208. ML157\* . (Weight= 50). M1 postprotocrista length: 0= indistinct to absent; 1= short; 2= long.
406. ML-209. ML158\* . (Weight= 50). M2 postprotocrista length: 0= indistinct to absent; 1= short; 2= long.
407. ML-210. ML159. (Weight= 100). M1 postprotocrista direction: 0= transverse, buccally directed; 1= lateral, directed toward the lingual posterior cingulum (post- protocone fold-like).
408. ML-211. ML160. (Weight= 100). M2 postprotocrista direction: 0= transverse, buccally directed; 1= lateral, directed toward lingual posterior cingulum (post- protocone fold-like).
409. ML-212. ML161. (Weight= 100). M1 postprotocrista terminus: 0= runs to base of metacone (with hypometacrasta); 1= runs to metaconule (at the level of the small or virtual metaconule); 2= runs to posterior cingulum; 3= limited at a point distal to protocone.

410. ML-213. ML162. (Weight= 100). M2 postprotocrista terminus: 0= runs to base of metacone (with hypometacrasta); 1= runs to metaconule (at the level of the small or virtual metaconule); 2= runs to posterior cingulum; 3= limited at a point distal to protocone.
411. ML-218. ML168\*. (Weight= 50). M1-2 hypometacrasta: 0= absent; 1= weakly developed (low and short); 2= well-developed (high).
412. ML-219. ML169\*. (Weight= 50). M1-2 hypoparacrasta: 0= absent; 1= weakly developed (short); 2= well-developed (high).
413. ML-220. MLN\*. (Weight= 50). Hypometaconulecrista (= metacrasta or crista obliqua): 0= indistinct to absent; 1= moderate (not connected to protocone); 2= well-developed (connected to protocone or postprotocrista).
414. ML-184. M22\*. (Weight= 33). M1-2 lingual cingulum development: 0= absent; 1= faintly visible; 2= well-defined; 3= strong.
415. ML-185. M22'. (Weight= 100). M1-2 lingual cingulum structure: 0= mesiodistally complete; 1= broken lingually (interrupted).
416. ML-197. ML147\*. (Weight= 50). M1-2 metastyle: 0= indistinct to absent; 1= moderate; 2= strong.
417. ML-198. ML148\*. (Weight= 50). M1-2 parastyle: 0= indistinct to absent; 1= moderate; 2= strong.
418. ML-201. ML151\*. (Weight= 50). M1-3 posterior cingulum: 0= weakly developed; 1= moderate, does not reach the metastyle; 2= connected to metastyle.
419. ML-202. ML151'\*. (Weight= 50). M1-2 posterior cingulum lobe (distomedial) inflation: 0= no inflation; 1= slightly inflated; 2= strongly inflated.
420. ML-203. ML152\*. (Weight= 50). M1-3 posterior margin (waisting between buccal and lingual cusps): 0= indistinct to absent; 1= present but shallow; 2= present, deep.
421. ML-204. ML153\*. (Weight= 33). M1-2 postparacrasta: 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).

422. ML-205. ML154\*. (Weight= 33). 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).

423. 268': (Weight= 50). M44'.\* M1-3 anterior cingulum: 0= strong; 1= weak; 2= absent.

424. 268'': (Weight= 33). M44''.\* M1-3 anterior cingulum: 0= complete (very long), reaches the parastyle; 1= long, stop at the level of the paraconule (or where a paraconule should occur); 2= short, does not reach the paraconule (or where a paraconule should occur); 3= very short, mesiolingually limited (not extended).

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Except as noted, characters of the cranium and permanent teeth are those used in Kay (1978, 1980), Kay et al. (1997, 2008a), Ross et al. (1998), and Marivaux et al., (2005, 2013).

Characters and character states of the deciduous teeth are based on Kay and Meldrum (1997).

Cranial characters adopted from Horovitz (1999) and Kay et al. (2004) are so designated. Many cranial and dental characters not specifically referenced are drawn from the following sources: Forsyth-Major (1901), Pocock (1925), Hill (1957, 1960, 1962), Le Gros Clark (1959), Du Brul (1965), Hershkovitz (1974, 1977), Cartmill (1978), Rosenberger (1979), Maier (1980), Conroy (1981), MacPhee and Cartmill (1986), Ross (1993, 1994), Beard and MacPhee (1994), Kay (1994), MacPhee et al. (1995), Horovitz

(1997), Kay et al. (1997), Ross et al. (1998), Horovitz (1999), Horovitz and MacPhee (1999), Kay and Kirk (2000), Lieberman et al. (2000), and Kay et al. (2006, 2008b).

The sources for postcranial characters are the comparative studies of: Evans and Krahl (1945), Napier and Davis (1959), Epple and Lorenz (1967), Lewis (1971), Schön and Ziemer (1973), Conroy (1976), Fleagle and Simons (1978, 1979, 1982, 1995), Ford (1980a, b, 1986, 1988, 1994), Szalay and Dagosto (1980), Rosenberger (1983), Gebo (1986), Dixson (1987), Fleagle and Kay (1987), Harrison (1987), Beard et al. (1988), Fleagle and Meldrum (1988), Hershkovitz (1988), Dagosto (1985, 1988, 1990), Ciochon (1993), Dagosto and Gebo (1994), Gebo et al. (1994, 2000), Dagosto et al. (1995, 1999), Dagosto and Schmid (1996), Rose (1996), Horovitz (1999), Simons and Seiffert (1999), Seiffert et al. (2000), Llorens et al. (2001), Seiffert and Simons (2001), and Marivaux et al. (2003, 2005).

## References

- Beard, K.C., MacPhee, R.D.E., 1994. Cranial anatomy of *Shoshonius* and the antiquity of Anthropoidea. In: Fleagle, J.G., Kay, R.F. (Eds.), *Anthropoid Origins: The Fossil Evidence*. Plenum Press, New York, pp. 55-98.
- Beard, K.C., Dagosto, M., Gebo, D.L., Godinot, M., 1988. Interrelationships among primate higher taxa. *Nature* 331, 712-714.
- Cartmill, M., 1978. The orbital mosaic in prosimians and the use of variable traits in systematics. *Folia Primatol.* 30, 89-114.
- Ciochon, R., 1993. *Evolution of the Cercopithecoid Forelimb. Phylogenetic and Functional Implications from Morphometric Analyses*. University Of California Press, Berkeley, CA.
- Conroy, G., 1981. Cranial asymmetry in ceboid primates: the emissary foramina. *Am. J. Phys. Anthropol.* 55, 187-194.

- Conroy, G.C., 1976. Primate Postcranial Remains from the Oligocene of Egypt. S. Karger, Basel.
- Dagosto, M., 1985. The distal tibia of primates with special reference to Omomyidae. *Int. J. Primatol.* 6, 45-75.
- Dagosto, M., 1988. Implications of postcranial evidence for the origin of Euprimates. *J. Hum. Evol.* 17, 35-56.
- Dagosto, M., 1990. Models for the origin of the anthropoid postcranium. *J. Hum. Evol.* 19, 121-139.
- Dagosto, M., Gebo, D.L., 1994. Postcranial anatomy and the origin of the Anthroidea. In: Fleagle, J.G., Kay, R.F. (Eds.), *Anthropoid Origins: The Fossil Evidence*. Plenum Press, New York, pp. 567-594.
- Dagosto, M., Schmid, P., 1996. Proximal femoral anatomy of omomyiform primates. *J. Hum. Evol.* 30, 29-56.
- Dagosto, M., Gebo, D.L., Beard, K.C., 1995. Postcranial anatomy of *Shoshonius cooperi*. *J. Vert. Paleontol.* 15, 25A.
- Dagosto, M., Gebo, D., Beard, K.C., 1999. Revision of the Wind River faunas, early Eocene of central Wyoming. Part 14. Postcranium of *Shoshonius cooperi* (Mammalia: Primates). *Ann. Carnegie Mus.* 68, 175-211.
- Dixson, A.F., 1987. Baculum length and copulatory behavior in primates. *Am. J. Primatol.* 13, 51-60.
- Du Brul, E.L., 1965. The skull of the lion marmoset, *Leontideus rosalia* Linnaeus: a study in biomechanical adaptation. *Am. J. Phys. Anthropol.* 23, 261-276.
- Epple, G., Lorenz, R., 1967. Vorkommen, morphologie und funktion der sternaldrüse bei den Platyrrhini. *Folia Primatol.* 7, 98-126.
- Evans, F.G., Krahl, V.E., 1945. The torsion of the humerus: A phylogenetic survey from fish to man. *Am. J. Anat.* 76, 303-337.
- Fleagle, J.G., Kay, R.F., 1987. The phyletic position of the Parapitheciidae. *J. Hum. Evol.* 16, 483-532.

- Fleagle, J.G., Meldrum, D.J., 1988. Locomotor behavior and skeletal morphology of two sympatric pitheciine monkeys, *Pithecia pithecia* and *Chiropotes satanas*. *Am. J. Primatol.* 16, 227-249.
- Fleagle, J.G., Simons, E.L., 1978. Humeral morphology of the early apes. *Nature* 276, 705-707.
- Fleagle, J.G., Simons, E.L., 1979. Anatomy of the bony pelvis in parapithecoid primates. *Folia Primatol.* 31, 176-186.
- Fleagle, J.G., Simons, E.L., 1982. The humerus of *Aegyptopithecus zeuxis*: a primitive anthropoid. *Am. J. Phys. Anthropol.* 59, 175-193.
- Fleagle, J.G., Simons, E.L., 1995. Limb skeleton and locomotor adaptations of *Apidium phiomense*, an Oligocene anthropoid from Egypt. *Am. J. Phys. Anthropol.* 97, 235-289.
- Ford, S.M., 1980a. A systematic revision of the Platyrrhini based on features of the postcranium. Ph.D. Dissertation, University of Pittsburgh, Pittsburgh.
- Ford, S.M., 1980b. Phylogenetic relationships of the Platyrrhini: the evidence of the femur. In: Ciochon, R.L., Chiarelli, A.B. (Eds.), *Evolutionary Biology of the New World Monkeys and Continental Drift*. Plenum Press, New York, pp. 317-329.
- Ford, S.M., 1986. Systematics of the New World monkeys. In: Swindler, D.R., Erwin, J. (Eds.), *Comparative Primate Biology, Volume I, Systematics, Evolution, and Anatomy*. Alan R. Liss, New York, pp. 73-135.
- Ford, S.M., 1988. Postcranial adaptations of the earliest platyrrhine. *J. Hum. Evol.* 17, 155-192.
- Ford, S.M., 1994. Primitive platyrrhines? Perspectives on anthropoid origins from platyrrhine, parapithecoid, and preanthropoid postcrania. In: Fleagle, J.G., Kay, R.F. (Eds.), *Anthropoid Origins: The Fossil Evidence*. Plenum Press, New York, pp. 595-676.
- Forsyth-Major, C.I., 1901. On some characters of the skull in the lemurs and monkeys. *Proc. Zool. Soc., London*, 1, 129-153.
- Gebo, D., 1986. Anthropoid origins - the foot evidence. *J. Hum. Evol.* 15, 421-430.

- Gebo, D.L., Simons, E.L., Rasmussen, D.T., Dagosto, M., 1994. Eocene anthropoid postcrania from the Fayum, Egypt. In: Fleagle, J.G., Kay, R.F. (Eds.), *Anthropoid Origins: The Fossil Evidence*. Plenum Press, New York, pp. 203-234.
- Gebo, D.L., Dagosto, M., Beard, K.C., Tao, Q., Wang, J., 2000. The oldest known anthropoid postcranial fossils and the early evolution of higher primates. *Nature* 404, 276-278.
- Harrison, T., 1997. The phylogenetic relationships of the early catarrhine primates: a review of the current evidence. *J. Hum. Evol.* 16, 41-80.
- Hershkovitz, P., 1974. A new genus of late Oligocene monkey (Cebidae, Platyrrhini) with notes on postorbital closure and platyrrhine evolution. *Folia Primatol.* 21, 1-35.
- Hershkovitz, P., 1977. *Living New World Monkeys (Platyrrhini) with an Introduction to Primates*, Vol. 1. University of Chicago Press, Chicago.
- Hershkovitz, P., 1988. The subfossil monkey femur and subfossil monkey tibia of the Antilles: a review. *Int. J. Primatol.* 9, 365-384.
- Hill, W.C.O., 1957. *Primates. Comparative Anatomy and Taxonomy. III Pithecoidea, Platyrrhini, Hapalidae*. University Press, Edinburgh.
- Hill, W.C.O., 1960. *Primates. Comparative Anatomy and Taxonomy. IV. Cebidae, Part A*. Wiley-Interscience, New York.
- Hill, W.C.O., 1962. *Primates. Comparative Anatomy and Taxonomy. Cebidae*. University Press, Edinburgh.
- Horovitz, I., 1997. *Platyrrhine systematics and the origin of Greater Antilles monkeys*. Ph.D. Dissertation, State University of New York at Stony Brook.
- Horovitz, I., 1999. A phylogenetic study of living and fossil platyrrhines. *Am. Mus. Novitates* 3269, 1-40.
- Horovitz, I., MacPhee, R.D.E., 1999. The Quaternary Cuban platyrrhine *Paralouatta varonai* and the origin of Antillean monkeys. *J. Hum. Evol.* 36, 33-68.
- Kay, R.F., 1978. Molar structure and diet in extant Cercopithecoidea. In: Butler, P.M., Joysey, K. (Eds.), *Development, Function and Evolution of Teeth*. Academic Press, London, pp. 309-339.

- Kay, R.F., 1980. Platyrrhine origins: a reappraisal of the dental evidence. In: Ciochon, R., Chiarelli, B. (Eds.), *Evolutionary Biology of the New World Monkeys and Continental Drift*. Plenum Press, New York, pp. 159-188.
- Kay, R.F., 1994. "Giant" tamarin from the Miocene of Colombia. *Am. J. Phys. Anthropol.* 95, 333-353.
- Kay, R.F., 2015. Biogeography in deep time - What do phylogenetics, geology, and paleoclimate tell us about early platyrrhine evolution? *Mol. Phylogenet. Evol.* 82, 358-374.
- Kay, R.F., Kirk, E.C., 2000. Osteological evidence for the evolution of activity pattern and visual acuity in primates. *Am. J. Phys. Anthropol.* 113, 235-262.
- Kay, R.F., Meldrum, D.J., 1997. A new small platyrrhine from the Miocene of Colombia and the phyletic position of Callitrichinae. In: Kay, R.F., Madden, R.H., Cifelli, R.L., Flynn, J.J. (Eds.), *Vertebrate Paleontology in the Neotropics*. Smithsonian Institution Press, Washington, D.C., pp. 435-458.
- Kay, R.F., Ross, C.F., Williams, B.A., 1997. Anthropoid origins. *Science* 275, 797-804.
- Kay, R.F., Williams, B.A., Ross, C.F., Takai, M., Shigehara, N., 2004. Anthropoid origins: a phylogenetic analysis. In: Ross, C.F., Kay, R.F. (Eds.), *Anthropoid Origins: New Visions*. Kluwer/Plenum, New York, pp. 91-135.
- Kay, R.F., Kirk, E.C., Malinzak, M., Colbert, M.W., 2006. Brain size, activity pattern, and visual acuity in *Homunculus patagonicus*, an early Miocene stem platyrrhine: the mosaic evolution of brain size and visual acuity in Anthropoidea. *J. Vert. Paleontol.* 26, 83A-84A.
- Kay, R.F., Fleagle, J.G., Mitchell, T.R.T., Colbert, M.W., Bown, T.M., Powers, D.W., 2008a. The anatomy of *Dolichocebus gaimanensis*, a primitive platyrrhine monkey from Argentina. *J. Hum. Evol.* 54, 323-382.
- Kay, R.F., Ross, J., Simons, E.L., 2008b. The basicranial anatomy of African Eocene/Oligocene anthropoids. Are there any clues for platyrrhine origins? In: Fleagle, J.G., Gilbert, C.G. (Eds.), *Elwyn L. Simons: A Search for Origins*. Springer, New York, pp. 125-158.

- Le Gros Clark, W.E., 1959. The Antecedents of Man. An Introduction to the Evolution of the Primates. Edinburgh University Press, Edinburgh.
- Lewis, O.J., 1971. The contrasting morphology found in the wrist joints of semibrachiating monkeys and brachiating apes. *Folia Primatol.* 16, 248-256.
- Lieberman, D.E., Ross, C., Ravosa, M.J., 2000. The primate cranial base: ontogeny, function, and integration. *Yearb. Phys. Anthropol.* 43, 117-169.
- Llorens, L., Casinos, A., Berge, C., Majoral, M., Jouffroy, F.-K., 2001. A biomechanical study of the long bones in platyrrhines. *Folia Primatol.* 72, 201-216.
- MacPhee, R.D.E., Cartmill, M., 1986. Basicranial structures and primate systematics. In: Swindler, D.R., Erwin, J. (Eds.), *Comparative Primate Biology, Volume 1: Systematics, Evolution, and Anatomy*. Alan R. Liss, New York, pp. 219-275.
- MacPhee, R.D.E., Horovitz, I., Arredondo, O., Jiménez Vázquez, O., 1995. A new genus for the extinct Hispaniolan monkey *Saimiri bernensis* Rímoli, 1977, with notes on its systematic position. *Am. Mus. Novitates* 3134, 1-21.
- Maier, W., 1980. Nasal structures in Old and New World primates. In: Ciochon, R., Chiarelli, B. (Eds.), *Evolutionary Biology of the New World Monkeys and Continental Drift*. Plenum Press, New York, pp. 219-241.
- Marivaux, L., 2006. The eosimiid and amphipithecoid primates (Anthropoidea) from the Oligocene of the Bugti Hills (Balochistan, Pakistan): New insight into early higher primate evolution in South Asia. *Palaeovertebrata* 34, 29-109.
- Marivaux, L., Chaimanee, Y., Ducrocq, R.-M., Marandt, B., Sudre, J., Soe, A.N., Tun, S.T., Htoon, W., Jaeger, J.-J., 2003. The anthropoid status of a primate from late middle Eocene Pondaung Formation (central Myanmar): tarsal evidence. *Proc. Natl. Acad. Sci.* 100, 13173-13178.
- Marivaux, L., Antoine, P.-O., Baqri, S.R.H., Benammi, M., Chaimanee, Y., Crochet, J.-Y., De Franceschi, D., Iqbal, N., Jaeger, J.-J., Métails, G., Roohi, G., Welcomme, J.-L., 2005. Anthropoid primates from the Oligocene of Pakistan (Bugti Hills): data on early anthropoid evolution and biogeography. *Proc. Natl. Acad. Sci.* 102, 8436-8441.

- Marivaux, L., Ramdarshan, A., Essid, E.M., Marzougui, W., Khayati Ammar, H., Lebrun, R., Marandat, B., Merzeraud, G., Tabuce, R., Vianey-Liaud, M., 2013. *Djebelemur*, a tiny pre-tooth-combed primate from the Eocene of Tunisia: a glimpse into the origin of crown strepsirhines. PLOS ONE 8, e80778.
- Napier, J., Davis, P.R., 1959. The Forelimb Skeleton and Associated Remains of *Proconsul africanus*. British Museum (Natural History), London.
- Pocock, R.I., 1925. Additional notes on the external characters of some platyrrhine monkeys. Proc. Zool. Soc., London 1925, 27-47.
- Rose, M.D., 1996. Functional morphological similarities in the locomotor skeleton of Miocene catarrhines and platyrrhine monkeys. Folia Primatol. 66, 7-14.
- Rosenberger, A.L., 1979. Phylogeny, evolution and classification of New World monkeys (Platyrrhini, Primates). Ph.D. Dissertation, University of New York.
- Rosenberger, A.L., 1983. Tale of tails: parallelism and prehensility. Am. J. Phys. Anthropol. 60, 103-107.
- Ross, C.F., 1993. The functions of the postorbital septum and anthropoid origins. Ph.D. Dissertation, Duke University, Durham.
- Ross, C.F., 1994. The craniofacial evidence for anthropoid and tarsier relationships. In: Fleagle, J.G., Kay, R.F. (Eds.), Anthropoid Origins: The Fossil Evidence. Plenum Press, New York, pp. 469-547.
- Ross, C., Williams, B.A., Kay, R.F., 1998. Phylogenetic analysis of anthropoid relationships. J. Hum. Evol. 35, 221-306.
- Schön, M.A., Ziemer, L.K., 1973. Wrist mechanism and locomotor behavior of *Dryopithecus (Proconsul) africanus*. Folia Primatol. 20, 1-11.
- Seiffert, E.R., Simons, E.L., 2001. Astragular morphology of late Eocene anthropoids from the Fayum Depression (Egypt) and the origin of catarrhine primates. J. Hum. Evol. 41, 577-606.
- Seiffert, E.R., Simons, E.L., Fleagle, J.G., 2000. Anthropoid humeri from the late Eocene of Egypt. Proc. Natl. Acad. Sci. 97, 10062-10067.

- Simons, E.L., Seiffert, E.R., 1999. A partial skeleton of *Proteopithecus sylviae* (Primates Anthroidea): first associated dental and postcranial remains of an Eocene anthropoidean. C. R. Acad. Sci., Paris 329, 921-927.
- Szalay, F.S., Dagosto, M., 1980. Locomotor adaptations as reflected on the humerus of Paleogene primates. Folia Primatol. 34, 1-45.