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SUPPLEMENTARY DATA

The cranial osteology of *Buitreraptor gonzalezorum* Makovicky, Apesteguía and Agnolín, 2005 (Theropoda, Dromaeosauridae), from the Late Cretaceous of Patagonia, Argentina

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Character list

Character 1: Vaned feathers on forelimb
0: symmetric
1: asymmetric
Character 2: Orbit shape
0: round in lateral or dorsolateral view
1: dorsoventrally elongate
Character 3: Anterior process of postorbital
0: projects into orbit
1: does not project into orbit
Character 4: Postorbital in lateral view
0: with straight anterior (frontal) process
1: frontal process curves anterodorsally and dorsal border of temporal bar is dorsally concave
Character 5: Postorbital bar
0: parallels quadrate, lower temporal fenestra rectangular in shape
1: jugal and postorbital approach or contact quadratojugal to constrict lower temporal fenestra
Character 6: Crista interfenestralis location
0: confluent with lateral surface of prootic and opisthotic
1: distinctly depressed within middle ear opening
Character 7: Subotic recess (pneumatic fossa ventral to fenestra ovalis)
0: absent
1: present
Character 8: Basisphenoid recess
0: present between basisphenoid and basioccipital
1: entirely within basisphenoid
2: absent
Character 9: Posterior opening of basisphenoid recess
0: single
1: divided into two small, circular foramina by a thin bar of bone
Character 10: Base of cultriform process (parasphenoid rostrum)
0: not highly pneumatized
1: expanded and pneumatic (parasphenoid bulla present)
Character 11: Basipterygoid processes project
0: ventral or anteroventrally projecting
1: lateroventrally projecting
2: laterally
Character 12: Basipterygoid processes
0: well developed, extending as a distinct process from the base of the basisphenoid
1: processes abbreviated or absent (1)
Character 13: Basipterygoid processes
0: solid
1: processes hollow
Character 14: Basipterygoid recesses on dorsolateral surfaces of basipterygoid processes
0: absent

1: present
Character 15: Depression for pneumatic recess on prootic (dorsal tympanic recess) ORDERED
0: absent
1: present as dorsally open fossa on prootic/opisthotic
2: present as deep, posterolaterally directed concavity
Character 16: Accessory tympanic recess dorsal to crista interfenestralis ORDERED
0: absent
1: small pocket present
2: extensive with indirect pneumatization
Character 17: Caudal (posterior) tympanic recess ORDERED
0: absent
1: present as opening on anterior surface of paroccipital process
2: extends into opisthotic posterodorsal to fenestra ovalis, confluent with this fenestra
Character 18: Exits of cranial nerves X–XII
0: flush with surface of exoccipital
1: located together in a bowllike depression
Character 19: Maxillary process of premaxilla
0: contacts nasal to form posterior border of nares
1: reduced so that maxilla participates broadly in external naris
2: extends posteriorly to separate maxilla from nasal posterior to nares
Character 20: Internarial bar shape
0: rounded
1: flat
Character 21: Crenulated margin on buccal edge of premaxilla
0: absent
1: present
Character 22: Position of caudal margin of naris (Chiappe et al., 1998)
0: farther rostral than the rostral border of the antorbital fossa
1: nearly reaching or overlapping the rostral border of the antorbital fossa
Character 23: Premaxillary symphysis shape
0: acute, V-shaped
1: rounded, U-shaped
Character 24: Secondary palate
0: short
1: long, with extensive palatal shelves on maxilla
Character 25: Palatal shelf of maxilla
0: flat
1: with midline ventral ‘‘toothlike’’ projection
Character 26: Pronounced, round accessory antorbital fenestra ORDERED
0: absent
1: present, fenestra occupies less than half of the depressed area between the anterior margins of the antorbital fossa and antorbital fenestra
2: present, fenestra large and takes up most of the space between the anterior margins of the antorbital fenestra and fossa
Character 27: Accessory antorbital fossa
0: situated at rostral border of antorbital fossa
1: situated posterior to rostral border of fossa
Character 28: Tertiary antorbital fenestra (fenestra promaxillaris)

0: absent
1: present
Character 29: Narial region
0: apneumatic or poorly pneumatized (0)
1: with extensive pneumatic fossae, especially along posterodorsal rim of naris
Character 30: Jugal and postorbital
0: both contribute equally to postorbital bar
1: ascending process of jugal reduced and descending process of postorbital ventrally elongate
Character 31: Jugal height beneath lower temporal fenestra
0: tall, twice or more as tall dorsoventrally as it is wide transversely
1: rodlike
Character 32: Jugal, pneumatic recess in posteroventral corner of antorbital fossa
0: present
1: absent
Character 33: Medial jugal foramen
0: present on medial surface ventral to postorbital bar
1: absent
Character 34: Quadratojugal shape
0: without horizontal process posterior to ascending process (reversed L shape)
1: with process (i.e., inverted T or Y shape)
Character 35: Jugal and quadratojugal
0: separate
1: quadratojugal and jugal fused and not distinguishable from one another
Character 36: Supraorbital crests on lacrimal in adult individuals
0: absent
1: dorsal crest above orbit
2: lateral expansion anterior and dorsal to orbit
Character 37: Enlarged foramen or foramina opening laterally at the angle of the lacrimal above antorbital fenestra
0: absent
1: present
Character 38: Lacrimal anterodorsal process
0: absent (inverted L shaped)
1: T-shaped in lateral view
2: anterodorsal process much longer than posterior process
Character 39: Prefrontal ORDERED
0: large, dorsal exposure similar to that of lacrimal
1: greatly reduced in size
2: absent
Character 40: Frontals
0: narrow anteriorly as a wedge between nasals
1: end abruptly anteriorly, suture with nasal transversely oriented
Character 41: Anterior emargination of supratemporal fossa on frontal (Currie, 1995)
0: straight or slightly curved
1: strongly sinusoidal and reaching onto postorbital process (1)
Character 42: Frontal postorbital process (dorsal view) (Currie, 1995)
0: smooth transition from orbital margin
1: sharply demarcated from orbital margin

Character 43: Frontal edge (Currie, 1995)
0: smooth in region of lacrimal suture
1: edge notched
Character 44: Dorsal surface of parietals
0: flat, lateral ridge borders supratemporal fenestra
1: parietals dorsally convex with very low sagittal crest along midline
2: dorsally convex with well-developed sagittal crest
Character 45: Parietals
0: separate
1: fused
Character 46: Descending process of squamosal
0: parallels quadrate shaft
1: lies nearly perpendicular to quadrate shaft
Character 47: Descending process of squamosal
0: contacts quadratojugal
1: does not contact quadratojugal
Character 48: Posterolateral shelf on squamosal overhanging quadrate head (Currie, 1995)
0: absent
1: present
Character 49: Quadrate orientation
0: vertical
1: strongly inclined anteroventrally so that distal end lies far forward of proximal end
Character 50: Lateral border of quadrate shaft (Currie, 1995)
0: straight
1: with broad, triangular process along lateral edge of shaft contacting squamosal and quadratojugal above an enlarged quadrate foramen
Character 51: Foramen magnum shape (Makovicky and Sues, 1998)
0: subcircular, slightly wider than tall
1: oval, taller than wide
Character 52: Occipital condyle
0: without constricted neck
1: subspherical with constricted neck
Character 53: Paroccipital process
0: elongate and slender, with dorsal and ventral edges nearly parallel
1: process short, deep with convex distal end
Character 54: Paroccipital process
0: straight, projects laterally or posterolaterally
1: distal end curves ventrally, pendant
Character 55: Paroccipital process (Currie, 1995)
0: with straight dorsal edge
1: with dorsal edge twisted rostrolaterally at distal end
Character 56: Ectopterygoid
0: with constricted opening into ventral fossa
1: with open ventral fossa in the main body of the element
Character 57: Dorsal recess on ectopterygoid
0: absent
1: present
Character 58: Flange of pterygoid

0: well developed
1: reduced in size or absent
Character 59: Palatine and ectopterygoid (Currie, 1995)
0: separated by pterygoid
1: contact
Character 60: Palatine shape (Elzanowski and Wellnhofer, 1996)
0: tetraradiate, with jugal process
1: palatine triradiate, jugal process absent
Character 61: Suborbital fenestra (Clark et al., 1994)
0: similar in length to orbit
1: reduced in size (less than one-quarter orbital length) or absent
Character 62: Symphyseal region of dentary
0: broad and straight, paralleling lateral margin
1: medially recurved slightly
2: strongly recurved medially
Character 63: Dentary symphyseal region
0: in line with main part of buccal edge
1: symphyseal end downturned
Character 64: Mandible
0: without coronoid prominence
1: with coronoid prominence
Character 65: Posterior end of dentary ORDERED
0: without posterodorsal process dorsal to mandibular fenestra
1: with dorsal process above anterior end of mandibular fenestra
2: with elongate dorsal process extending over most of fenestra
Character 66: Labial face of dentary (Russell and Dong, 1993)
0: flat
1: with lateral ridge and inset tooth row
Character 67: Dentary shape (Currie, 1995)
0: subtriangular in lateral view
1: with subparallel dorsal and ventral edges
Character 68: Nutrient foramina on external surface of dentary (Currie, 1987)
0: superficial
1: lying within deep groove
Character 69: External mandibular fenestra shape
0: oval
1: subdivided by a spinous rostral process of the surangular
Character 70: Internal mandibular fenestra (Currie, 1995)
0: small and slitlike
1: large and rounded
Character 71: Foramen in lateral surface of surangular rostral to mandibular articulation
0: absent
1: present
Character 72: Splenial
0: not widely exposed on lateral surface of mandible
1: exposed as a broad triangle between dentary and angular on lateral surface of mandible
CHARACTER EXCLUDED: *Coronoid ossification* (ch. 76 of Turner et al., 2012)

0: large
1: only a thin splint
2: absent
This character considers the form of the coronoid ossification or the absence of it, although it is similar to the character 275 (280 of Turner et al., 2012), which considers the presence/absence of this ossification. We opted to keep the character 275 because it is clearer in the definition of their states.
Character 73: Articular
0: without elongate, slender medial, posteromedial, or mediodorsal process from retroarticular process
1: with process
Character 74: Retroarticular process
0: short, stout
1: elongate and slender
Character 75: Mandibular articulation surface
0: as long as distal end of quadrate
1: twice or more as long as quadrate surface, allowing anteroposterior movement of mandible
Character 76: Premaxilla
0: toothed
1: edentulous
Character 77: Second premaxillary tooth (Currie, 1995)
0: approximately equivalent in size to other premaxillary teeth
1: second tooth markedly larger than third and fourth premaxillary teeth
Character 78: Maxilla
0: toothed
1: edentulous
Character 79: Maxillary and dentary teeth
0: serrated
1: some without serrations anteriorly (except at base in *S. mongoliensis*)
2: all without serrations
Character 80: Dentary and maxillary teeth
0: large
1: small (25–30 in dentary)
Character 81: Dentary teeth (Currie, 1987)
0: in separate alveoli
1: set in open groove
Character 82: Serration denticles (Farlow et al., 1991, quantify this difference)
0: large
1: small
Character 83: Serrations
0: simple, denticles convex
1: distal and often mesial edges of teeth with large, hooked denticles that point toward the tip of the crown
Character 84: Teeth
0: constricted between root and crown
1: root and crown confluent
Character 85: Dentary teeth
0: evenly spaced

1: anterior dentary teeth smaller, more numerous, and more closely appressed than those in middle of tooth row
Character 86: Dentaries
0: lack distinct interdental plates
1: with interdental plates medially between teeth.
Character 87: In cross section, premaxillary tooth crowns
0: suboval to subcircular
1: asymmetrical (D-shaped in cross section) with flat lingual surface
Character 88: Number of cervical vertebrae
0: #10 (0)
1: 12 or more
Character 89: Axial epipophyses
0: absent or poorly developed, not extending past posterior rim of postzygapophyses
1: large and posteriorly directed, extend beyond postzygapophyses
Character 90: Axial neural spine
0: flared transversely
1: compressed mediolaterally
Character 91: Epipophyses of cervical vertebrae
0: placed distally on postzygapophyses, above postzygapophyseal facets
1: placed proximally, proximal to postzygapophyseal facets
Character 92: Anterior cervical centra
0: level with or shorter than posterior extent of neural arch
1: centra extending beyond posterior limit of neural arch
Character 93: Carotid process on posterior cervical vertebrae
0: absent
1: present
Character 94: Anterior cervical centra (Gauthier, 1986)
0: subcircular or square in anterior view
1: distinctly wider than high, kidney shaped
Character 95: Cervical neural spines (Makovicky and Sues, 1998)
0: anteroposteriorly long
1: short and centered on neural arch, giving arch an X shape in dorsal view
Character 96: Cervical centra (Gauthier, 1986)
0: with one pair of pneumatic openings
1: with two pairs of pneumatic openings
Character 97: Cervical and anterior trunk vertebrae
0: amphiplatyan
1: opisthocoelous
2: at least partially heterocoelous
Character 98: Anterior trunk vertebrae (Gauthier, 1986)
0: without prominent hypapophyses
1: with large hypapophyses
Character 99: Parapophyses of posterior trunk vertebrae (Norell and Makovicky, 1999)
0: flush with neural arch
1: distinctly projected on pedicels
Character 100: Hyposphene-hypantrum articulations in trunk vertebrae
0: absent
1: present
Character 101: Zygapophyses of trunk vertebrae

0: abutting one another above neural canal, opposite hyposphenes meet to form lamina
1: lateral to neural canal and separated by groove for interspinous ligaments, hyposphenes separated
Character 102: Cervical vertebrae pneumaticity
0: absent
1: present
Character 103: Transverse processes of anterior dorsal vertebrae
0: long and thin
1: short, wide, and only slightly inclined
Character 104: Neural spines of dorsal vertebrae
0: not expanded distally
1: expanded to form ‘‘spine table’’
Character 105: Scars for interspinous ligaments
0: terminate at apex of neural spine in dorsal vertebrae
1: terminate below apex of neural spine
Character 106: Number of sacral vertebrae ORDERED
0: 5 or fewer
1: 6
2: 7
3: 8
4: 9
5: 10
6: 11 or more
7: 15 or more
Character 107: Sacral vertebrae
0: with unfused zygapophyses
1: with fused zygapophyses forming a sinuous ridge in dorsal view
Character 108: Ventral surface of posterior sacral centra
0: gently rounded, convex
1: ventrally flattened, sometimes with shallow sulcus
2: centrum strongly constricted transversely, ventral surface keeled
Character 109: Pleurocoels ORDERED
0: absent on sacral vertebrae
1: present on anterior sacrals only
2: present on all sacrals
Character 110: Last sacral centrum
0: with flat posterior articulation surface
1: convex articulation surface
Character 111: Free caudal vertebrae
0: with distinct transition point, from shorter centra with long transverse processes proximally to longer centra with small or no transverse processes distally
1: vertebrae homogeneous in shape, without transition point
Character 112: Transition point in caudal series
0: distal to the 10th caudal vertebra
1: between the 7th and 10th caudal vertebra
2: proximal to the 7th caudal vertebra
Character 113: Anterior caudal centra (modified from Gauthier, 1986)
0: tall, oval in cross section
1: with boxlike centra in caudals I–V

2: anterior caudal centra laterally compressed with ventral keel
Character 114: Neural spines of caudal vertebrae (Russell and Dong, 1993)
0: simple, undivided
1: separated into anterior and posterior alae throughout much of caudal sequence
Character 115: Neural spines on distal caudals (Russell and Dong, 1993)
0: form a low ridge
1: spine absent
2: midline sulcus in center of neural arch
Character 116: Prezygapophyses of distal caudal vertebrae
0: between 1/3 and 1 centrum length
1: with extremely long extensions of the prezygapophyses (up to 10 vertebral segments long in some taxa)
2: strongly reduced or absent
3: prezygapophyses clasping the posterior surface of neural arch of preceding vertebrae, postzygapophyses negligible
Character 117: Number of caudal vertebra (modified from Turner et al., 2007)
0: more than 40 caudal vertebrae
1: 25–40 caudal vertebrae
2: no more than 25 caudal vertebrae
3: very short, fewer than 8 free caudal vertebrae
Character 118: Proximal end of chevrons of proximal caudals
0: short anteroposteriorly, shaft cylindrical
1: proximal end elongate anteroposteriorly, flattened and platelike
Character 119: Distal caudal chevrons
0: simple
1: anteriorly bifurcate
2: bifurcate at both ends
Character 120: Shaft of cervical ribs
0: slender and longer than vertebra to which they articulate
1: broad and shorter than vertebra
Character 121: Ossified uncinate processes ORDERED
0: absent
1: present and unfused to ribs
2: fused to ribs
Character 122: Ossified ventral (sternal) rib segments
0: absent
1: present
Character 123: Lateral gastral segment
0: shorter than medial one in each arch
1: distal segment longer than proximal segment
Character 124: Ossified sternal plates
0: separate in adults
1: fused
Character 125: Sternum
0: without distinct lateral xiphoid process posterior to costal margin
1: with lateral xiphoid process
Character 126: Anterior edge of sternum
0: grooved for reception of coracoids
1: sternum without grooves

Character 127: Articular facet of coracoid on sternum (conditions may be determined by the articular facet on coracoid in taxa without ossified sternum)
0: anterolateral or more lateral than anterior
1: almost anterior
Character 128: Hypocledium on furcula ORDERED
0: absent
1: present as tubercle
2: present as an elongate process
Character 129: Acromion margin of scapula
0: continuous with blade
1: anterior edge laterally everted
Character 130: Posterolateral surface of coracoids ventral to glenoid fossa
0: unexpanded
1: posterolateral edge of coracoid expanded to form triangular subglenoid fossa bounded laterally by enlarged coracoid tuber
Character 131: Scapula and coracoid
0: separate
1: fused into scapulacoracoid
Character 132: Coracoid in lateral view
0: subcircular, with shallow ventral blade
1: subquadrangular with extensive ventral blade
2: shallow ventral blade with elongate posteroventral process
3: height more than twice width—coracoid strutlike
Character 133: Scapula and coracoid
0: form a continuous arc in posterior and anterior views
1: coracoid inflected medially, scapulocoracoid L shaped in lateral view
Character 134: Glenoid fossa faces
0: posteriorly or posterolaterally
1: laterally
Character 135: Scapula length
0: longer than humerus
1: humerus longer than scapula
Character 136: Deltopectoral crest
0: large and distinct, proximal end of humerus quadrangular or triangular in anterior view
1: deltopectoral crest less pronounced, forming an arc rather than being quadrangular
2: deltopectoral crest very weakly developed, proximal end of humerus with rounded edges
3: deltopectoral crest extremely long and rectangular
Character 137: Anterior surface of deltopectoral crest
0: smooth
1: with distinct muscle scar near lateral edge along distal end of crest for insertion of biceps muscle
Character 138: Olecranon process
0: weakly developed
1: distinct and large
Character 139: Distal articular surface of ulna (dorsal condyle and dorsal trochlea in birds)
0: flat

1: convex, semilunate surface (1).
Character 140: Proximal surface of ulna
0: a single continuous articular facet
1: divided into two distinct fossae (one convex, the other concave) separated by a median ridge
Character 141: Lateral proximal carpal (ulnare?)
0: quadrangular
1: triangular in proximal view
Character 142: Two distal carpals in contact with metacarpals
0: one covering the base of metacarpal I (and perhaps contacting metacarpal II) the other covering the base of metacarpal II
1: a single distal carpal capping metacarpals I and II
Character 143: Semilunate distal carpal
0: well developed, covering all of proximal ends of metacarpals I and II
1: small, covers about half of base of metacarpals I and II
2: covers bases of all metacarpals
3: covers MC II and MC III
Character 144: Metacarpal I
0: half or less than half the length of metacarpal II, and longer proximodistally than wide transversely
1: subequal in length to metacarpal II
2: very short and wider transversely than long proximodistally
Character 145: Third manual digit
0: present, phalanges present
1: reduced to no more than metacarpal splint
Character 146: Manual unguals
0: strongly curved, with large flexor tubercles
1: weakly curved with weak flexor tubercles displaced distally from articular end
2: straight with weak flexor tubercles displaced distally from articular end
3: absent
Character 147: Unguals on all digits
0: generally similar in size
1: digit I bearing large ungual and unguals of other digits distinctly smaller
Character 148: Proximodorsal ‘‘lip’’ on some manual unguals—a transverse ridge immediately dorsal to the articulating surface
0: absent
1: present
Character 149: Ventral edge of anterior ala of ilium
0: straight or gently curved
1: ventral edge with shallow, obtuse process
2: process strongly hooked
Character 150: Preacetabular part of ilium
0: roughly as long as postacetabular part of ilium
1: preacetabular portion of ilium markedly longer (more than 2/3 of total ilium length) than postacetabular part
2: postacetabular blade much longer
Character 151: Anterior end of ilium
0: gently rounded or straight
1: anterior end strongly convex, lobate

2: pointed at anterodorsal corner with concave anteroventral edge
3: distinctly concave dorsally
Character 152: Supraacetabular crest on ilium as a separate process from antitrochanter, forms ‘‘hood’’ over femoral head ORDERED
0: present
1: reduced, not forming hood
2: absent
Character 153: Postacetabular ala of ilium in lateral view
0: squared
1: acuminate
Character 154: Postacetabular blades of ilia in dorsal view
0: subparallel
1: diverge posteriorly
Character 155: Tuber along dorsal edge of ilium, dorsal or slightly posterior to acetabulum
0: absent
1: present
Character 156: Brevis fossa
0: shelflike
1: deeply concave with lateral overhang
Character 157: Antitrochanter posterior to acetabulum
0: absent or poorly developed
1: prominent
Character 158: Ridge bounding cuppedicus fossa
0: terminates rostral to acetabulum or curves ventrally onto anterior end of pubic peduncle
1: rim extends far posteriorly and is confluent or almost confluent with acetabular rim
Character 159: Cuppedicus fossa
0: deep, ventrally concave
1: fossa shallow or flat, with little or no lateral overhang
2: absent
Character 160: Posterior edge of ischium
0: straight
1: with proximal median posterior process
Character 161: Ischium
0: with rodlike shaft [i.e., part distal to acetabular portion]
1: with wide, flat, and platelike shaft
Character 162: Ischiadic shaft
0: straight
1: ventrodistally curved anteriorly
2: hooked posteriorly
Character 163: Lateral face of ischiadic blade
0: flat [or round in rodlike ischia]
1: laterally concave
2: with longitudinal ridge subdividing lateral surface into anterior (including obturator process) and posterior parts
Character 164: Obturator process of ischium ORDERED
0: absent
1: proximal in position

2: located near middle of ischiadic shaft
3: located at distal end of ischium
Character 165: Obturator process
0: does not contact pubis
1: contacts pubis
Character 166: Obturator notch
0: present
1: notch or foramen absent
Character 167: Semicircular scar on posterior part of the proximal end of the ischium
0: absent
1: present
Character 168: Ischium
0: more than 2/3 of pubis length
1: 2/3 or less of pubis length
Character 169: Distal ends of ischia ORDERED
0: form symphysis
1: approach one another but do not form symphysis
2: widely separated
Character 170: Ischial boot (expanded distal end)
0: present
1: absent
Character 171: Tubercle on anterior edge of ischium
0: absent
1: present
Character 172: Pubis orientation
0: propubic
1: vertical
2: posteriorly oriented (opisthopubic)
3: appressed to ischium
Character 173: Pubic boot projects
0: anteriorly and posteriorly
1: with little or no anterior process
2: no anteroposterior projections
Character 174: Shelf on pubic shaft proximal to symphysis (‘‘pubic apron’’)
0: extends medially from middle of cylindrical pubic shaft
1: shelf extends medially from anterior edge of anteroposteriorly flattened shaft
2: absent
Character 175: Pubic shaft
0: straight
1: distal end curves anteriorly, anterior surface of shaft concave
2: shaft curves posteriorly, anteriorly convex curvature
Character 176: Pubic apron
0: about half of pubic shaft length
1: less than 1/3 of shaft length
Character 177: Contact between pubic apron
0: contributions of both pubes meet extensively
1: contact disrupted by a slit
2: no contact
Character 178: Femoral head

0: without fovea capitalis (for attachment of capital ligament)
1: or circular fovea present in center of medial surface of head
Character 179: Lesser trochanter
0: separated from greater trochanter by deep cleft
1: trochanters separated by small groove
2: completely fused (or absent) to form a trochanteric crest
Character 180: Lesser trochanter of femur
0: alariform
1: cylindrical in cross section
Character 181: Lateral ridge
0: absent or represented only by faint rugosity
1: distinctly raised from shaft, moundlike
Character 182: Fourth trochanter on femur
0: present
1: absent
Character 183: Accessory trochanteric crest distal to lesser trochanter
0: absent
1: present
Character 184: Anterior surface of femur proximal to medial distal condyle
0: without longitudinal crest
1: crest present extending proximally from medial condyle on anterior surface of shaft
Character 185: Popliteal fossa between ends of femur
0: open distally
1: closed off distally by contact between distal condyles
Character 186: Fibula
0: reaches proximal tarsals
1: short, tapering distally, and not in contact with proximal tarsals
Character 187: Medial surface of proximal end of fibula
0: concave along long axis
1: flat
Character 188: Deep oval fossa on medial surface of fibula near proximal end
0: absent
1: present
Character 189: Distal end of astragalus and calcaneum
0: with condyles separated by shallow, indefinite sulcus
1: with distinct condyles separated by prominent tendoneal groove on anterior surface
Character 190: Tibia, cnemial crest(s)
0: lateral crest only
1: lateral and anterior crests developed (1)
Character 191: Ascending process of the astragalus
0: tall and broad, covering most of anterior surface of distal end of tibia
1: process short and slender, covering only lateral half of anterior surface of tibia
2: ascending process tall, but with medial notch that restricts it to lateral side of anterior face of distal tibia
Character 192: Ascending process of astragalus
0: confluent with condylar portion
1: separated by transverse groove or fossa across base
Character 193: Calcaneum and astragalus ORDERED
0: unfused to each other or tibia in adult

1: fused to each other, unfused to tibia
2: completely fused to each other and tibia
Character 194: Distal tarsals
0: separate, not fused to metatarsals
1: fuses to metatarsal
Character 195: Metatarsals ORDERED
0: not coossified
1: coossification of metatarsals begins proximally
2: metatarsals fuse to each other proximally and distally
3: extreme distal fusion, distal vascular foramen closed
Character 196: Distal end of metatarsal II
0: smooth, not ginglymoid
1: with developed ginglymus
Character 197: Distal end of metatarsal III
0: smooth, not ginglymoid
1: with developed ginglymus
Character 198: Metatarsal III proximal shaft
0: prominently exposed between metatarsal II and metatarsal IV along entire metapodium
1: metatarsal III proximal shaft constricted and much narrower than either II or IV, but still exposed along most of metapodium, subarctometatarsal
2: very pinched, not exposed along proximal section of metapodium, arctometatarsal
3: proximal part of metatarsal III lost
Character 199: Ungual and penultimate phalanx of pedal digit II
0: similar to those of III
1: penultimate phalanx highly modified for extreme hyperextension, ungual more strongly curved and significantly larger than that of digit III
Character 200: Metatarsal I articulates with
0: the middle of the medial surface of metatarsal II
1: the posterior surface of distal quarter of metatarsal II
2: the medial surface of metatarsal II near its proximal end
3: the medial surface of at the distal end
Character 201: Metatarsal I
0: attenuates proximally, without proximal articulating surface
1: proximal end of metatarsal I similar to that of metatarsals II–IV
Character 202: Shaft of metatarsal IV
0: round or thicker dorsoventrally than wide in cross section
1: shaft of metatarsal IV mediolaterally widened and flat in cross section
Character 203: Foot
0: symmetrical
1: asymmetrical with slender metatarsal II and very robust metatarsal IV, excluding flange
Character 204: Neural spines on posterior dorsal vertebrae in lateral view
0: rectangular or square
1: anteroposteriorly expanded distally, fan shaped
Character 205: Shaft diameter of manual phalanx I-1
0: less than shaft diameter of radius.
1: greater than shaft diameter of radius.

Character 206: Angular
0: exposed almost to end of mandible in lateral view, reaches or almost reaches articular
1: excluded from posterior end angular suture turns ventrally and meets ventral border of mandible rostral to glenoid
Character 207: Laterally inclined flange along dorsal edge of surangular for articulation with lateral process of lateral quadrate condyle
0: absent
1: present
Character 208: Distal articular ends of metacarpals I + II
0: ginglymoid
1: rounded, smooth
2: II ginglymoid and metacarpal I shelf
Character 209: Radius and ulna
0: well separated
1: with distinct adherence or syndesmosis distally
Character 210: Jaws
0: occlude for their full length
1: diverge rostrally due to kink and downward deflection in dentary buccal margin
Character 211: Quadrate head
0: covered by squamosal in lateral view
1: quadrate cotyle of squamosal open laterally exposing quadrate head
Character 212: Brevis fossa
0: poorly developed adjacent to ischial peduncle and without lateral overhang, medial edge of brevis fossa visible in lateral view
1: fossa well developed along full length of postacetabular blade, lateral overhang extends along full length of fossa, medial edge completely covered in lateral view
Character 213: Vertical ridge on lesser trochanter
0: present
1: absent
Character 214: Supratemporal fenestra
0: bounded laterally and posteriorly by the squamosal
1: extends as a fossa on to the dorsal surface of the squamosal
Character 215: Dentary
0: fully toothed
1: only with teeth rostrally
2: edentulous
Character 216: Posterior edge of coracoid
0: not or only shallowly indented below glenoid
1: deeply notched just ventral to glenoid, glenoid lip everted
Character 217: Retroarticular process
0: points caudally
1: curves gently dorsocaudally
Character 218: Flange on supraglenoid buttress on scapula (Nicholls and Russell, 1985)
0: absent
1: present
Character 219: Depression (possibly pneumatic) on ventral surface of postorbital process of laterosphenoid (Makovicky et al., 2003)
0: absent

1: present
Character 220: Basal tubera
0: set far apart, level with or beyond lateral edge of occipital condyle and/or foramen magnum (may connected by a web of bone or separated by a large notch)
1: small, directly below condyle and foramen magnum, and separated by a narrow notch
2: absent
Character 221: Dorsal edge of postacetabular blade (Novas, 2004)
0: convex or straight
1: concave, brevis shelf extending caudal to vertical face of ilium giving ilium a dorsally concave outline in lateral view
Character 222: Postacetabular end of ilium
0: terminating in rounded or square end in dorsal view
1: with lobate brevis shelf projecting from end of ilium and beyond end of postacetabular lamina
Character 223: Flexor heel on phalanx II-2
0: small and asymmetrically developed only on medial side of vertical ridge subdividing proximal articulation
1: heel long and lobate, with extension of midline ridge extending onto its dorsal surface
Character 224: Large, longitudinal flange along caudal or lateral face of metatarsal IV
0: absent
1: present
Character 225: Proximodorsal process of ischium
0: small, tablike or pointed process along caudal edge of ischium
1: process large proximodorsally hooked and separated from iliac peduncle of the ischium by a notch
Character 226: Lateral face of pubic shaft
0: smooth
1: with prominent lateral tubercle about halfway down the shaft
Character 227: Distally placed dorsal process along caudal edge of ischiadic shaft (Forster et al., 1998)
0: absent
1: present
Character 228: Obturator process
0: square (i.e., with distinct caudal edge or notch)
1: triangular with caudal end confluent with shaft
Character 229: Triangular obturator process with
0: short rostral projection and wide base along ischial shaft
1: short base, long process extending rostrally
Character 230: Tuber along extensor surface metatarsal II (associated with the insertion of the tendon of the m. tibialis cranialis in Aves) ORDERED
0: absent
1: present, on approximately the center of the proximodorsal surface of metatarsal II
2: present, developed on lateral surface of metatarsal II, at contact with metatarsal III or on lateral edge of metatarsal III
Character 231: Ulna/femoral length ratio
0: significantly less than one
1: equal or greater than one
Character 232: Dorsal displacement of accessory (maxillary) fenestra
0: absent

1: present
Character 233: Jugal process of maxilla, ventral to the external antorbital fenestra
0: dorsoventrally narrow
1: dorsoventrally wide
Character 234: Accessory antorbital (maxillary) fenestra recessed within a shallow, caudally or caudodorsally open fossa, which is itself located within the maxillary antorbital fossa
0: absent
1: present
Character 235: Nasal process of maxilla, dorsal ramus (ascending ramus of maxilla):
0: prominent, exposed medially and laterally
1: absent or reduced to slight medial, and no lateral exposure
Character 236: In lateral view, participation of the ventral ramus of the nasal process of the maxilla in the anterior margin of the internal antorbital fenestra
0: present extensively
1: small dorsal projection of the maxilla participates in the anterior margin
2: no dorsal projection of maxilla participates in the anterior margin
Character 237: In lateral view, dorsal border of the internal antorbital fenestra formed by
0: lacrimal and maxilla
1: lacrimal and nasal
Character 238: In lateral view, dorsal border of the antorbital fossa formed by
0: lacrimal and maxilla
1: lacrimal and nasal
2: maxilla, premaxilla, and lacrimal
Character 239: In lateral view, lateral lamina of the ventral ramus of nasal process of maxilla
0: present, large broad exposure
1: present, reduced to small triangular exposure
Character 240: Supratemporal fossa
0: with limited extension onto dorsal surfaces of frontal and postorbital
1: covers most of frontal process of the postorbital and extends anteriorly onto dorsal surface of frontal
Character 241: Jugal
0: does not particulate in margin of antorbital fenestra
1: participates in antorbital fenestra
Character 242: Anterior and posterior denticles of teeth
0: not significantly different in size
1: anterior denticles, when present, significantly smaller than posterior denticles
Character 243: Maxillary teeth
0: almost perpendicular to jaw margin
1: inclined strongly posteroventrally
Character 244: Maxillary tooth height
0: highly variable with gaps evident for replacement
1: almost isodont with no replacement gaps
Character 245: Splenial forms notched anterior margin of internal mandibular fenestra
0: absent
1: present

Character 246: First premaxillary tooth size compared with crowns of premaxillary teeth 2 and 3
0: slightly smaller or same size
1: much smaller
2: much larger
Character 247: Maxilla, promaxillary fenestra in adults
0: visible in lateral view
1: obscured in lateral view by ascending ramus of maxilla
Character 248: Nasal
0: dorsally flat for most of length
1: dorsally convex
Character 249: Nasal
0: unfused
1: fused
Character 250: Squamosal-quadratojugal flange constricting infratemporal fenestra
0: absent
1: present
Character 251: Supraoccipital, pronounced, strongly demarcated median ridge
0: absent
1: present
Character 252: Surangular, anteroventral extension divides external mandibular fenestra by contacting angular anteriorly
0: absent
1: present
Character 253: Surangular, posterior surangular foramen
0: small
1: large fenestra
Character 254: Vertical ridge on iliac blade above acetabulum
0: absent or poorly developed
1: well developed
Character 255: Shape of premaxillary body
0: wider than high or approximately as wide as high
1: significantly higher than wide
Character 256: Dorsal surface of the nasals
0: smooth
1: rugose
Character 257: Sublacrimal part of jugal
0: tapering
1: bluntly squared anteriorly
2: expanded
3: bifurcated
Character 258: Axial neural spine
0: sheetlike
1: anteroposteriorly reduced and rodlike
Character 259: Prezygapophyses in anterior postaxial cervicals
0: straight
1: anteroposteriorly convex, flexed ventrally anteriorly
Character 260: Pleurocoels in dorsal vertebrae ORDERED

0: absent
1: present in anterior dorsals
2: present in all dorsals
Character 261: Ratio femur/humerus ORDERED
0: more than 2.5
1: between 1.2 and 2.2
2: less than 1
Character 262: Humerus in lateral view
0: sigmoidal
1: straight
Character 263: Radius
0: more than half the length of humerus
1: less than half the length of humerus
Character 264: Premaxillae ORDERED
0: unfused in adults
1: fused anteriorly in adults, posterior nasal [frontal] processes not fused to each other
2: frontal processes completely fused as well as anterior premaxillae
Character 265: Dentaries
0: joined proximally by ligaments
1: joined by bone
Character 266: Mandibular symphysis, two strong grooves forming an anteriorly opening V in ventral view
0: absent
1: present
Character 267: Facial margin ORDERED
0: primarily formed by the maxilla, with the maxillary process of the premaxilla restricted to the anterior tip
1: maxillary process of the premaxilla extending ½ facial margin
2: maxillary process of the premaxilla extending more than ½ of facial margin
Character 268: Nasal [frontal] process of premaxilla
0: short
1: long, closely approaching frontal
Character 269: Osseous external naris
0: considerably smaller than the antorbital fenestra
1: larger than the antorbital fenestra
Character 270: Ectopterygoid
0: present
1: absent
Character 271: Articulation between vomer and pterygoid
0: present, well developed
1: reduced, narrow process of pterygoid passes dorsally over palatine to contact vomer
2: absent, pterygoid and vomer do not contact
Character 272: Palatine and pterygoid
0: long, anteroposteriorly overlapping, contact
1: short, primarily dorsoventral, contact
Character 273: Palatine contacts
0: maxillae only
1: premaxillae and maxillae
Character 274: Vomer contacts premaxilla

0: present
1: absent
Character 275: Coronoid ossification
0: present
1: absent
CHARACTER EXCLUDED: *Projecting basisphenoid articulation with pterygoid* (ch. 281 of Turner et al., 2012)
0: present
1: absent
This character was excluded because it refers to the articulation of the basisphenoid with the pterygoid, which is through the basipterygoid processes, and thus it overlaps with character 12 (13 of Turner et al., 2012), which refers to the form and presence/absence of these processes.
Character 276: Basisphenoid-pterygoid articulations
0: located basal on basisphenoid
1: located markedly anterior on basisphenoid (parasphenoid rostrum) such that the articulations are subadjacent on the narrow rostrum
Character 277: Basisphenoid-pterygoid articulation, orientation of contact
0: anteroventral
1: mediolateral
2: entirely dorsoventral
Character 278: Pterygoid, articular surface for basisphenoid ORDERED
0: concave ‘‘socket,’’ or short groove enclosed by dorsal and ventral flanges
1: flat to convex
2: flat to convex facet, stalked, variably projected
Character 279: Pterygoid, kinked
0: present, surface for basisphenoid articulation at high angle to axis of palatal process of pterygoid
1: absent, articulation in line with axis of pterygoid
Character 280: Osseous interorbital septum (mesethmoid)
0: absent
1: present
Character 281: Osseous interorbital septum (mesethmoid)
0: restricted to posterior or another just surpassing premaxillae/frontal contact in rostral extent does not surpass posterior edge of external nares in rostral extent
1: extending rostral to posterior extent of frontal processes of premaxillae and rostral to posterior edge of external nares
Character 282: Eustachian tubes
0: paired and lateral
1: paired, close to cranial midline
2: paired and adjacent on midline or single anterior opening
Character 283: Eustachian tubes ossified
0: absent
1: present
Character 284: Squamosal, ventral or ‘‘zygomatic’’ process
0: variably elongate, dorsally enclosing otic process of the quadrate and extending anteroventrally along shaft of this bone, dorsal head of quadrate not visible in lateral view
1: short, head of quadrate exposed in lateral view

Character 285: Orbital process of quadrate, pterygoid articulation
0: pterygoid broadly overlapping medial surface of orbital process (i.e., ‘‘pterygoid ramus’’)
1: restricted to anteromedial edge of process
Character 286: Quadrate, orbital process ORDERED
0: pterygoid articulates with anteriormost tip
1: pterygoid articulation does not reach tip
2: pterygoid articulation with no extent up orbital process, restricted to quadrate corpus
Character 287: Quadrate/pterygoid contact
0: as a facet, variably with slight anteromedial projection cradling base
1: condylar, with a well-projected tubercle on the quadrate
Character 288: Quadrate, well-developed tubercle on anterior surface of dorsal process
0: absent
1: present
Character 289: Quadrate, quadratojugal articulation
0: overlapping
1: peg and socket articulation
Character 290: Quadrate, dorsal process, articulation
0: with squamosal only
1: with squamosal and prootic
Character 291: Quadrate, dorsal process, development of intercotylar incisure between prootic and squamosal cotylae
0: absent, articular surfaces not differentiated
1: two distinct articular facets, incisure not developed
2: incisure present, ‘‘double headed’’
Character 292: Quadrate, mandibular articulation
0: bicondylar articulation with mandible
1: tricondylar articulation, additional posterior condyle or broad surface
Character 293: Quadrate, pneumaticity
0: absent
1: present
Character 294: Quadrate, cluster of pneumatic foramina on posterior surface of the tip of dorsal process
0: absent
1: present
Character 295: Quadrate, pneumatization, large, single pneumatic foramen
0: absent
1: posteromedial surface of corpus
Character 296: Articular pneumaticity
0: absent
1: present
Character 297: Dentary strongly forked posteriorly
0: unforked, or with a weakly developed dorsal ramus
1: strongly forked with the dorsal and ventral rami approximately equal in posterior extent
Character 298: Splenial, anterior extent
0: splenial stops well posterior to mandibular symphysis
1: extending to mandibular symphysis, though noncontacting
2: extending to proximal tip of mandible, contacting on midline

Character 299: Mandibular symphysis, anteroposteriorly extensive, flat to convex, dorsalfacing surface developed
0: absent, concave
1: flat surface developed
Character 300: Mandibular symphysis, symphyseal foramina
0: absent
1: present
Character 301: Mandibular symphysis, symphyseal foramen/foramina
0: single
1: paired
Character 302: Mandibular symphysis, symphyseal foramen/foramina
0: opening on posterior edge of symphysis
1: opening on dorsal surface of symphysis
Character 303: Meckel's groove
0: not completely covered by splenial, deep and conspicuous medially
1: covered by splenial, not exposed medially
Character 304: Anterior external mandibular fenestra
0: absent
1: present
Character 305: Jugal/postorbital contact
0: present
1: absent
Character 306: Frontal/parietal suture
0: open
1: fused
Character 307: Thoracic vertebrae, count ORDERED
0: 12 or more
1: 11
2: 10 or fewer
Character 308: Thoracic vertebrae
0: at least part of series with subround, central articular surfaces (e.g., amphicoelous/opisthocoelous) that lack the dorsoventral compression seen in heterocoelous vertebrae
1: series completely heterocoelous
Character 309: Thoracic vertebrae, parapophyses
0: rostral to transverse processes
1: directly ventral to transverse processes (close to midpoint of vertebrae)
Character 310: Thoracic vertebrae, centra, length, and midpoint width
0: approximately equal in length and midpoint width
1: length markedly greater than midpoint width
CHARACTER EXCLUDED: *Thoracic vertebrae (with ribs articulating with the sternum), one or more with prominent hypapophyses* (ch. 313 of Turner et al., 2012)
0: absent
1: present
This character was excluded because it refers to a condition very similar to that expressed by the character 98 (102 of Turner et al., 2012). Anterior trunk vertebrae can have ribs articulating with the sternum in some taxa.
CHARACTER EXCLUDED: *Thoracic vertebrae, lateral surfaces of centra* (ch. 318 of Turner et al., 2012)

0: flat to slightly depressed
1: deep, emarginated fossae
2: central ovoid foramina
This character was excluded because it refers to the presence or absence of an excavation on the lateral surface of thoracic vertebrae, and thus can be confused with the presence/absence of a pleurocoel, which is considered by the character 260 (265 of Turner et al., 2012).
Character 311: Thoracic vertebrae with ossified connective tissue bridging transverse processes
0: absent
1: present
Character 312: Notarium
0: absent
1: present
Character 313: Sacral vertebrae, series of short vertebrae, with dorsally directed parapophyses just anterior to the acetabulum ORDERED
0: absent
1: present, 3 such vertebrae
2: present, 4 such vertebrae
Character 314: Anterior free caudals prior to transition point; length of transverse processes
0: subequal to width of centrum
1: significantly shorter than centrum width
Character 315: Distal caudals
0: unfused
1: fused
Character 316: Fused distal caudals, morphology ORDERED
0: fused element length equal or greater than 4 free caudal vertebrae
1: length less than 4 caudal vertebrae
2: less than 2 caudal vertebrae in length
Character 317: Gastralia
0: present
1: absent
Character 318: Carina or midline ridge ORDERED
0: absent
1: slightly raised
2: distinctly projected
Character 319: Carina or midline ridge
0: restricted to posterior half of sternum
1: approaches anterior limit of sternum
2: restricted to the anterior half of the sternum
Character 320: Sternum, dorsal surface, pneumatic foramen (or foramina)
0: absent
1: present
Character 321: Sternum, pneumatic foramina in the depressions (loculi costalis; Baumel and Witmer, 1993) between rib articulations (processi articularis sternocostalis; Baumel and Witmer, 1993)
0: absent
1: present

Character 322: Sternum, coracoidal sulci spacing on anterior edge
0: widely separated mediolaterally
1: adjacent
2: crossed on midline
Character 323: Sternum, number of processes for articulation with the sternal ribs ORDERED
0: 3
1: 4
2: 5
3: 6
4: 7 or more
Character 324: Sternum: raised, paired intermuscular ridges (linea intermuscularis; Baumel and Witmer, 1993) parallel to sternal midline
0: absent
1: present
Character 325: Sternum, posterior margin, distinct posteriorly projected medial and/or lateral processes ORDERED
0: absent (directly laterally projected zyphoid processes developed but not considered homologes as these are copresent with the posterior processes in the new clade)
1: with distinct posterior processes
2: midpoint of posterior sternal margin connected to medial posterior processes to enclose paired fenestra
Character 326: Clavicles
0: fused
1: unfused
Character 327: Interclavicular angle (clavicles elongate)
0: greater than or equal to 90º
1: less than 90º
Character 328: Furcula, laterally excavated
0: absent
1: present
Character 329: Furcula, dorsal tip
0: flat or blunt tip
1: with a pronounced posteriorly pointed tip
Character 330: Furcula, ventral margin of apophysis
0: curved, angled
1: with a truncate or squared base
Character 331: Scapula and coracoids articulation
0: pit-shaped scapular cotyla developed on the coracoid, and coracoidal tubercle developed on the scapula (‘‘ball and socket’’ articulation)
1: scapular articular surface of coracoid convex
2: flat
Character 332: Coracoid, procoracoid process
0: absent
1: present
Character 333: Coracoid, lateral margin
0: straight to slightly concave
1: convex

Character 334: Coracoid, dorsal surface (= posterior surface of basal maniraptoran theropods)
0: strongly concave
1: flat to convex
Character 335: Coracoid, pneumatized
0: absent
1: present
Character 336: Coracoid, pneumatic foramen
0: proximal
1: distal
Character 337: Coracoid, lateral process
0: absent
1: present
Character 338: Coracoid, ventral surface, lateral intermuscular line or ridge
0: absent
1: present
Character 339: Coracoid, glenoid facet
0: dorsal to, or at approximately same level as, acrocoracoid process/‘‘biceps tubercle’’
1: ventral to acrocoracoid process
Character 340: Coracoid, acrocoracoid
0: straight
1: hooked medially
Character 341: Coracoid, n. supracoracoideus passes through coracoid
0: present
1: absent
Character 342: Coracoid, medial surface, area of the foramen n. supracoracoideus (when developed)
0: strongly depressed
1: flat to convex
Character 343: Angle between coracoids and scapula at glenoid
0: more than 90u
1: 90u or less
Character 344: Scapula, posterior end
0: wider or approximately the same width as proximal dorsoventral shaft width
1: tapering distally
Character 345: Scapula
0: straight
1: dorsoventrally curved
Character 346: Scapula, acromion process
0: projected anteriorly to surpass the articular surface for coracoid (facies articularis coracoidea; Baumel and Witmer, 1993)
1: projected less anteriorly than the articular surface for coracoid
Character 347: Scapula, acromion process
0: straight
1: laterally hooked tip
Character 348: Humerus and ulna, length ORDERED
0: humerus longer than ulna
1: ulna and humerus approximately the same length
2: ulna significantly longer than humerus

Character 349: Humerus, proximal end, head in anterior or posterior view
0: straplike, articular surface flat, no proximal midline convexity
1: head domed proximally
Character 350: Humerus, proximal end, proximal projection
0: dorsal edge projected farthest
1: midline projected farthest
Character 351: Humerus, ventral tubercle and capital incisure
0: absent
1: present
Character 352: Humerus, capital incisure
0: an open groove
1: closed by tubercle associated with a muscle insertion just distal to humeral head
Character 353: Humerus, anterior surface, well-developed fossa on midline making proximal articular surface appear V-shaped in proximal view
0: absent
1: present
Character 354: Humerus, ‘‘transverse groove’’
0: absent
1: present, developed as a discreet, depressed scar on the proximal surface of the bicipital crest or as a slight transverse groove
Character 355: Humerus, deltopectoral crest
0: projected dorsally (in line with the long axis of humeral head)
1: projected anteriorly
Character 356: Humerus, deltopectoral crest ORDERED
0: less than shaft width
1: same width
2: dorsoventral width greater than shaft width
Character 357: Humerus, deltopectoral crest, proximoposterior surface
0: flat to convex
1: concave
Character 358: Humerus, deltopectoral crest
0: not perforate
1: with a large fenestra
Character 359: Humerus, bicipital crest, pit-shaped scar/fossa for muscular attachment on anterodistal, distal or posterodistal surface of crest
0: absent
1: present
Character 360: Humerus, bicipital crest, pit-shaped fossa for muscular attachment
0: anterodistal on bicipital crest
1: directly ventrodistal at tip of bicipital crest
2: posterodistal, variably developed as a fossa
Character 361: Humerus, bicipital crest ORDERED
0: little or no anterior projection
1: developed as an anterior projection relative to shaft surface in ventral view
2: hypertrophied, rounded tumescence
Character 362: Humerus, proximal end, one or more pneumatic foramina
0: absent
1: present
Character 363: Humerus, distal condyles

0: developed distally
1: developed on anterior surface of humerus
Character 364: Humerus, long axis of dorsal condyle
0: at low angle to humeral axis, proximodistally orientated
1: at high angle to humeral axis, almost transversely orientated
Character 365: Humerus, distal condyles
0: subround, bulbous
1: weakly defined, ‘‘straplike’’
Character 366: Humerus, distal margin
0: approximately perpendicular to long axis of humeral shaft
1: ventrodistal margin projected significantly distal to dorsodistal margin, distal margin angling strongly ventrally (sometimes described as a well-projected flexor process)
Character 367: Humerus, distal end, compressed anteroposteriorly and flared dorsoventrally
0: absent
1: present
Character 368: Humerus, brachial fossa
0: absent
1: present, developed as a flat scar or as a scarimpressed fossa
Character 369: Humerus, ventral condyle
0: length of long axis of condyle less than the same measure of the dorsal condyle
1: same or greater than same measure of the dorsal condyle
Character 370: Humerus, demarcation of muscle origins (e.g., m. extensor metacarpi radialis in Aves) on the dorsal edge of the distal humerus
0: no indication of origin as a scar, a pit, or a tubercle
1: indication as a pit-shaped scar or as a variably projected scar-bearing tubercle or facet
Character 371: Humerus, distal end, posterior surface, groove for passage of m. scapulotriceps
0: absent
1: present
Character 372: Humerus, m. humerotricipitalis groove
0: absent
1: present as a ventral depression contiguous with the olecranon fossa
Character 373: Ulna, cotylae
0: dorsoventrally adjacent
1: widely separated by a deep groove
Character 374: Ulna, dorsal cotyla convex
0: absent
1: present
Character 375: Ulna, distal end, dorsal condyle, dorsal trochlear surface, extent along posterior margin
0: less than transverse measure of dorsal trochlear surface
1: approximately equal in extent
Character 376: Ulna, bicipital scar ORDERED
0: absent
1: developed as a slightly raised scar
2: developed as a conspicuous tubercle
Character 377: Ulna, brachial scar
0: absent

1: present
Character 378: Radius, ventroposterior surface
0: smooth
1: with muscle impression along most of surface
2: deep longitudinal groove
Character 379: Ulnare
0: absent
1: present
Character 380: Ulnare
0: ‘‘heart shaped,’’ little differentiation into short dorsal and ventral rami
1: V-shaped, well-developed dorsal and ventral rami
Character 381: Ulnare, ventral ramus (crus longus, Baumel and Witmer, 1993)
0: shorter than dorsal ramus (crus brevis)
1: same length as dorsal ramus
2: longer than dorsal ramus
Character 382: Semilunate carpal and metacarpals ORDERED
0: no fusion
1: incomplete proximal fusion
2: complete proximal fusion
3: complete proximal and distal fusion
Character 383: Metacarpal III, anteroposterior diameter as a percent of same dimension of metacarpal II
0: approximately equal or greater than 50%
1: less than 50%
Character 384: Metacarpal I, anteroproximally projected muscular process ORDERED
0: absent no distinct process visible
1: small knob at anteroproximal tip of metacarpal
2: tip of process just surpasses the distal articular facet for phalanx 1 in anterior extent
3: tip of extensor process conspicuously surpasses articular facet by approximately half the width of facet, producing a pronounced knob
4: tip of extensor process conspicuously surpasses articular facet by approximately the width of facet, producing a pronounced knob
Character 385: Metacarpal I, anterior surface
0: roughly hourglass shaped proximally, at least moderately expanded anteroposteriorly, and constricted just before flare of articulation for phalanx 1
1: anterior surface broadly convex
Character 386: Pisiform process
0: absent
1: present
Character 387: Carpometacarpus, ventral surface, supratrochlear fossa deeply excavating proximal surface of pisiform process
0: absent
1: present
Character 388: Intermetacarpal space (between metacarpals II and III)
0: reaches proximally as far as the distal end of metacarpal I
1: terminates distal to end of metacarpal I
Character 389: Carpometacarpus, distal end, metacarpals II and III, articular surfaces for digits
0: metacarpal II subequal or surpasses metacarpal III in distal extent

1: metacarpal III extends further
Character 390: Intermetacarpal process or tubercle ORDERED
0: absent
1: present as scar
2: present as tubercle or flange
Character 391: Manual digit II, phalanx 1
0: subcylindrical to subtriangular
1: strongly dorsoventrally compressed, flat caudal surface
Character 392: Manual digit II, phalanges
0: length of phalanx II-1 less than or equal to that of II-2
1: longer
Character 393: Manual digit II, phalanx 2, internal index process on posterodistal edge
0: absent
1: present
Character 394: Ilium, ischium, pubis, proximal contact in adult ORDERED
0: unfused
1: partial fusion (pubis not ankylosed)
2: completely fused
Character 395: Ilium/ischium, distal coossification to completely enclose the ilioischiadic fenestra
0: absent
1: present
Character 396: Ischium, dorsal process
0: does not contact ilium
1: contacts ilium
Character 397: Laterally projected process on ischiadic peduncle (antitrochanter)
0: directly posterior to acetabulum
1: posterodorsal to acetabulum
Character 398: Ilium, preacetabular pectineal process (Baumel and Witmer, 1993) ORDERED
0: absent
1: present as a small flange
2: present as a well-projected flange
Character 399: Preacetabular ilium
0: approach on midline, open, or cartilaginous connection
1: coossified, dorsal closure of ‘‘iliosynsacral canals’
Character 400: Preacetabular ilium extends anterior to first sacral vertebrae
0: no free ribs overlapped
1: one or more ribs overlapped
Character 401: Postacetabular ilium
0: dorsoventrally orientated
1: mediolaterally orientated
Character 402: Postacetabular ilium, ventral surface, renal fossa developed
0: absent
1: present
Character 403: Ilium, m. cuppedicus fossa as broad, mediolaterally oriented surface directly anteroventral to acetabulum
0: present

1: surface absent, insertion variably marked by a small entirely lateral fossa anterior to acetabulum
Character 404: Pubis
0: suboval in cross section
1: compressed mediolaterally
Character 405: Pubes, distal contact
0: contacting, variably coossified into symphysis
1: noncontacting
Character 406: Femur, posterior trochanter ORDERED
0: present, developed as a slightly projected tubercle or flange
1: hypertrophied, ‘‘shelflike’’ conformation (in combination with development of the trochanteric shelf; see Hutchinson, 2001)
2: absent
Character 407: Femur, patellar groove
0: absent
1: present
Character 408: Femur, ectocondylar tubercle and lateral condyle
0: separated by deep notch
1: form single trochlear surface
Character 409: Femur, posterior projection of the lateral border of the distal end, continuous with lateral condyle
0: absent
1: present
Character 410: Laterally projected fibular trochlea ORDERED
0: absent
1: present, developed as small notch
2: a shelflike projection
Character 411: Tibia/tarsal formed condyles
0: medial condyle projecting further anteriorly than lateral
1: equal in anterior projection
Character 412: Tibia/tarsal formed condyles, extensor canal ORDERED
0: absent
1: an emarginated groove
2: groove bridged by an ossified supratendoneal bridge
Character 413: Tibia/tarsal formed condyles, tuberositas retinaculi extensoris (Baumel and Witmer, 1993) indicated by short medial ridge or tubercle proximal to the condyles close to the midline and a more proximal second ridge on the medial edge
0: absent
1: present
Character 414: Tibia/tarsal formed condyles, mediolateral widths ORDERED
0: medial condyle wider
1: approximately equal
2: lateral condyle wider
Character 415: Tibia/tarsal formed condyles
0: gradual sloping medial constriction of condyles
1: no medial tapering of either condyle
Character 416: Tibia/tarsal formed condyles, intercondylar groove
0: mediolaterally broad, approximately 1/3 width of anterior surface
1: less than 1/3 width of total anterior surface

Character 417: Tibia, extension of articular surface for distal tarsals/tarsometatarsus ORDERED
0: no posterior extension of trochlear surface, or restricted to distalmost edge of posterior surface
1: well-developed posterior extension, sulcus cartilaginis tibialis of Aves (Baumel and Witmer, 1993), distinct surface extending up the posterior surface of the tibiotarsus
2: with well-developed, posteriorly projecting medial and lateral crests
Character 418: Tibia, distalmost mediolateral width
0: wider than midpoint of shaft, giving distal profile a weakly developed triangular form
1: approximately equal to shaft width, no distal expansion of whole shaft, although condyles may be variably splayed mediolaterally
Character 419: Metatarsal V
0: present
1: absent
Character 420: Metatarsal III
0: proximally in plane with II and IV
1: proximally displaced plantarly, relative to metatarsals II and IV
Character 421: Tarsometatarsus, inter cotylar eminence
0: absent
1: well developed, globose
Character 422: Tarsometatarsus, projected surface or grooves on proximoposterior surface (associated with the passage of tendons of the pes flexors in Aves; hypotarsus) ORDERED
0: absent
1: developed as posterior projection with flat posterior surface
2: projection, with distinct crests and grooves
3: at least one groove enclosed by bone posteriorly
Character 423: Tarsometatarsus, proximal vascular foramen (foramina) ORDERED
0: absent
1: one, between metatarsals III and IV
2: two
Character 424: Metatarsal I ORDERED
0: straight
1: curved or distally deflected but not twisted, ventral surface convex ‘‘J shaped’’
2: deflected and twisted such that the ventromedial surface is concave proximal to trochlear surface for phalanx I
Character 425: Metatarsal II, distal plantar surface, fossa for metatarsal I ORDERED [fossa metatarsi I; Baumel and Witmer, 1993]
0: absent
1: shallow notch
2: conspicuous ovoid fossa
Character 426: Metatarsals, relative mediolateral width
0: metatarsal IV approximately the same width as metatarsal II
1: metatarsal IV narrower than MII and MIII
2: metatarsal IV greater in width than either metatarsal II or III
Character 427: Metatarsals, comparative trochlear width
0: II approximately the same size as III and/or IV
1: II wider than III and/or IV
2: II narrower than III and/or IV

3: IV narrowest.
Character 428: Distal vascular foramen
0: simple, with one exit
1: forked, two exits (plantar and distal) between metatarsals III and IV.
Character 429: Metatarsal III, trochlea in plantar view, proximal extent of lateral and medial edges of trochlea
0: absent, trochlear edges approximately equal in proximal extent
1: present, lateral edge extends further
Character 430: Metatarsal II, distal extent of metatarsal II relative to metatarsal IV ORDERED
0: approximately equal in distal extent
1: metatarsal II shorter than metatarsal IV, but reaching distally further than base of metatarsal IV trochlea
2: metatarsal II shorter than metatarsal IV, reaching distally only as far as base of metatarsal IV trochlea.
Character 431: Middle to posterior caudal vertebrae
0: 2x or less the length of dorsal vertebrae
1: 3x–4x length of dorsal vertebrae
Character 432: Coracoid fenestra
0: absent
1: present
Character 433: Metatarsal V, elongated and bowed
0: absent
1: present
Character 434: Posterior extension of caudal chevrons
0: not significantly elongated
1: very elongated
Character 435: Radius width
0: roughly half or greater than width of ulna
1: less than half width of ulna
Character 436: Combined length of metacarpal
I plus phalanx I-1
0: greater than length of metacarpal II
1: equal to or less than length of metacarpal II
Character 437: Metacarpal III
0: straight
1: bowed
Character 438: Metatarsal I
0: distal end of trochlea proximally placed relative to other metatarsals
1: inline distally with others
Character 439: Metatarsal I
0: present
1: absent
Character 440: Development of the preotic pendant ORDERED
0: absent
1: present but small
2: present and robust
Character 441: Shape of the metotic strut
0: short and robust

1: long and narrow
Character 442: Prootic recess ORDERED
0: absent
1: present and shallow
2: present and deep
Character 443: Anterior tympanic recess (ATR)
0: absent (i.e., not deeply impressed into the lateral wall of basisphenoid)
1: present and impressed into the lateral wall of the basisphenoid
Character 444: Location of ATR and the anterior tympanic crista
0: below cranial nerve VII exit just proximal to the otic recess
1: anteriorly with little or no development posterior to the basipterygoid processes
Character 445: ATR confluent with the subotic recess
0: absent
1: present, forming the lateral depression
Character 446: V-shaped opening between basal tubera remnants
0: absent
1: present
Character 447: Small tubera (not basal tubera) medial to basal tubera (or basal tubera remnants) and ventral to occipital condyle
0: absent
1: present
Character 448: Pedal phalanx II-2, distal articular surface relative to proximal articular surface
0: approximately equal in size, distal surface slightly smaller than proximal
1: distal surface less than half the size of proximal surface
Character 449: Sternal plates
0: unossified
1: ossified
Character 450: Ulna, size of proximal cotylae
0: unequal, lateral (dorsal in birds) smaller
1: equal
Character 451: Middle ear resides within the lateral depression
0: absent
1: present
Character 452: Filamentous integumentary structures (stage 1 feathers)
0: absent
1: present
Character 453: Vaned feathers (stage 4 feathers)
0: absent
1: present
Character 454: Quadratojugal size
0: large
1: greatly reduced
Character 455: Notch for postorbital contact on postorbital process of frontal
0: absent, process smooth or facet small
1: large notch present
Character 456: Position of frontoparietal suture relative to postorbital processes of frontal
0: well posterior to the postorbital processes

1: at the level of the postorbital processes
2: anterior to postorbital processes
Character 457: Orientation of articular surfaces between cervical vertebrae
0: surfaces vertical to subvertical
1: strongly slanted anteroventrally
Character 458: Accessory depression in supra temporal fossa
0: absent
1: present
Character 459: Relative ventral extension of pubic versus ischiadic peduncles
0: equal
1: pubic peduncle extends farther ventrally
Character 460: Ala parasphenoidalis
0: absent
1: present, well developed and crest shaped, forming anterior edge of enlarged pneumatic recess with the ala continuous with the anterior tympanic crista
Character 461: (Nesbitt et al., 2009) Cross section of the furcula
0: nearly circular
1: anteroposteriorly compressed near the symphysis
Character 462: (Nesbitt et al., 2009) General shape of the furcula
0: V-shaped
1: U-shaped
Character 463: (Nesbitt et al., 2009) Epicledial processes
0: unexpanded
1: expanded
Character 464: (Nesbitt et al., 2009) Lateral expansión of the rami between the hypocledium and the epicledial process
0: absent
1: present
Character 465: (Nesbitt et al., 2009) Hypocledium
0: rounded
1: keeled
Character 466: (Nesbitt et al., 2009) Furcula
0: asymmetrical
1: nearly symmetrical
Character 467: (Nesbitt et al., 2009) Furcula rami
0: thin
1: thick
Character 468: Anterior (dorsal) surface of metatarsal III
0: relatively narrow and flat
1: transversely expanded in the distal portion of the shaft, partially covering the anterior surface of the metatarsals II and IV (MODIFIED)
The state 1 was modified in order to propose a state reflecting more specifically the morphology observed in the taxa used in this analysis, especially considering the present condition in *Buitreraptor*, other unenlagiines and other taxa with subarctometatarsal condition.
Character 469: (Turner et al., 2009) Accessory longitudinal ridge on anterolateral side of the distal end of metatarsal IV
0: absent
1: present

Added characters

Character 470: Length of the skull
0: less than the length of the femur
1: the same or 25% greater than the length of the femur (NEW)
2: more than 25% the length of the femur
Modified from Novas et al. (2009). A new state 1 was added because some taxa, e.g., *Yanornis martini*, have a skull longer than the femur but less than 25% of the length of this bone.
Character 471: Postantral wall of the maxilla posteriorly extended (Novas et al., 2009)
0: absent
1: present
Character 472: Striations on the crowns of the teeth (Gianechini et al., 2009, 2011)
0: absent
1: present
Striations on the crowns are considered as two or more longitudinal furrows on the labial and/or lingual surface. Isolated furrows, as those observed in *Sinornithosaurus millenii*, are not considered as striations.

Characters from Hu et al. (2009)

Character 473: Dorsal centra
0: ≥ 1.2×taller than long
1: height ≤ length
Character 474: Length of manual digit II (including metacarpal)
0: less than 1.25×femoral length
1: ≥ 1.25×femoral length
Character 475: Manual phalanx I-1 (Pérez-Moreno et al., 1994)
0: longer than metacarpal II
1: shorter than metacarpal II
Character 476: Strong kink of pubis at midshaft
0: absent
1: present, displacing distal half of pubis caudally
Character 477: In adult, femur length
0: longer than tibia
1: shorter than tibia
Character 478: Metatarsus length
0: less than half length of femur
1: more than half femoral length
Character 479: Length of pedal phalanx II-2
0: between 0.6×and 1× length of phalanx II-1
1: ≤0.6 × length of phalanx II-1
2: ≥1× length of phalanx II-1
Character 480: Manual phalanx II-1
0: shorter than I-1
1: longer than I-1
Character 481: Pneumatopores in anterior caudal vertebrae
0: absent
1: present

Character 482: Length of manual phalanx III-2
0: subequal to length of phalanx III-1
1: significantly shorter than phalanx III-1
2: significantly longer than phalanx III-1
Character 483: Location of the anteroventral process of ilium
0: anteriorly located, close to the anterior end of the bone
1: posteriorly located, significantly away from the anterior end
Character 484: Location of the postorbital process of the jugal
0: located significantly anterior to the posterior end of the jugal
1: close to the posterior end, and consequently the quadratojugal process is very short

New characters

Character 485: Inclination of the ventral process of the lacrimal
0: ventrally directed so the process is vertical
1: anteroventrally inclined
Character 486: Inclination of the dorsal portion of the ilium above or slightly posterior to the acetabulum
0: in the same plane than the remain of the iliac blade
1: strongly laterally curved, so the lateral surface of the iliac blade can be observed in ventral view
Character 487: Extension of the supracetabular crest of the ilium
0: extended only along the dorsal border of the acetabulum
1: anteriorly extended along the lateral surface of the pubic peduncle, reaching or almost reaching the ventral end of the peduncle
Character 488: Angle between the posterior border of the pubic shaft and the dorsal border of the pubic boot
0: less than 90°
1: greater than 90°
Character 489: Dorsal surface of the acetabulum
0: perpendicular with the lateral surface of the iliac blade, so the acetabulum is totally open
1: dorsal surface of the acetabulum ventrally and medially inclined, so the acetabulum tends to be obliterated
Character 490: Anteroposterior extension of the pubic peduncle
0: less than the anteroposterior extension of the acetabulum
1: between 1 and 1.5 the anteroposterior extension of the acetabulum
2: > 1.5 the anteroposterior extension of the acetabulum
Character 491: Foramen in the ventral part of the splenial (mylohyoid foramen) (character from Rauhut, 2003):
0: absent
1: completely enclosed in the splenial
2: opened anteroventrally
Character 492: Middle of maxillary tooth row, spacing between teeth:
0: narrow, teeth separated by less than one crown width
1: wide, adjacent teeth separated by a gap corresponding to one crown width or more.

List of synapomorphies obtained for Paraves and the nodes within it, including autapomorphies of Unenlagiinae taxa

Paraves
All trees:
Char. 129: 0 --> 1
Char. 134: 0 --> 1
Char. 168: 0 --> 1
Char. 175: 0 --> 2

Avialae
All trees:
Char. 1: 0 --> 1
Char. 17: 1 --> 2
Char. 45: 1 --> 0
Char. 50: 1 --> 0
Char. 112: 1 --> 2
Char. 150: 0 --> 1
Char. 176: 0 --> 1
Char. 200: 01 --> 3
Char. 231: 0 --> 1
Char. 238: 0 --> 1
Char. 261: 1 --> 2
Char. 277: 0 --> 1
Char. 278: 0 --> 1
Char. 310: 1 --> 0
Char. 418: 0 --> 1
Char. 441: 0 --> 1
Char. 474: 0 --> 1
Char. 483: 0 --> 1
Char. 490: 0 --> 1
Char. 491: 1 --> 0
Some trees:
Char. 160: 0 --> 1
Char. 436: 0 --> 1
Char. 479: 0 --> 2

Deinonychosauria
All trees:
Char. 38: 0 --> 2
Char. 58: 1 --> 0
Char. 71: 0 --> 1
Char. 105: 0 --> 1
Char. 199: 0 --> 1
Some trees:
Char. 158: 0 --> 1
Char. 163: 0 --> 2
Char. 468: 0 --> 01

Troodontidae
All trees:
Char. 20: 0 --> 1
Char. 49: 0 --> 1
Char. 68: 0 --> 1
Char. 85: 0 --> 1
Char. 189: 0 --> 1
Char. 198: 0 --> 2
Char. 449: 1 --> 0
Some trees:
Char. 7: 0 --> 1
Char. 187: 0 --> 1

Dromeosauridae
All trees:
Char. 16: 1 --> 0
Char. 53: 1 --> 0
Char. 55: 0 --> 1
Char. 92: 1 --> 0
Char. 99: 0 --> 1
Char. 196: 0 --> 1
Char. 444: 0 --> 1
Some trees:
Char. 84: 0 --> 1
Char. 468: 0 --> 1

Unenlaiinae
All trees:
Char. 152: 2 --> 1
Char. 172: 2 --> 1
Char. 221: 0 --> 1
Some trees:
Char. 160: 0 --> 1
Char. 223: 1 --> 0

Buitreraptor + (*Austroraptor* + *Unenlagia*)
All trees:
Char. 198: 0 --> 1
Char. 224: 0 --> 1
Char. 331: 2 --> 1
Some trees:
Char. 163: 0 --> 2

Austroraptor + *Unenlagia*
All trees:
Char. 104: 0 --> 1

Rahonavis ostromi
All trees:

Char. 108: 1 --> 0
Char. 109: 0 --> 1
Char. 114: 0 --> 1
Char. 169: 1 --> 2
Char. 176: 0 --> 1
Char. 179: 1 --> 2
Char. 186: 0 --> 1
Char. 202: 0 --> 1
Char. 227: 0 --> 1
Char. 230: 0 --> 1
Char. 231: 0 --> 1
Char. 410: 0 --> 1
Char. 435: 0 --> 1
Char. 487: 1 --> 0
Char. 490: 1 --> 2
Some trees:
Char. 163: 2 --> 0

Buitreraptor gonzalezorum
All trees:
Char. 68: 0 --> 1
Char. 92: 0 --> 1
Char. 193: 1 --> 2
Char. 366: 0 --> 1
Char. 486: 0 --> 1
Char. 492: 0 --> 1

Unenlagia
All trees:
No autapomorphies

Austroraptor cabazai
All trees:
Char. 137: 1 --> 0
Char. 356: 0 --> 1

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