SUPPLEMENTAL APPENDICES TO

TURNER, POL, AND NORELL (2011)

APPENDIX 1: SPECIMEN LIST

Collection numbers of the specimens that were revised first-hand by the authors are added after the bibliographic reference.

Achillobator giganticus (Perle et al., 1999; FR.MNUFR-15)

Adasaurus mongoliensis (Barsbold, 1983a; IGM 100/20, IGM 100/21; IGM 100/22; IGM 100/23)

Albertosaurus sarcophagus (Currie, 2003)

Allosaurus fragilis (Madsen, 1976; AMNH FR 257, AMNH FR 275, AMNH FR 281, AMNH FR 287, AMNH FR 290, UMNH VP 16605, UMNH 16652, UUVP 5961)

Alvarezsaurus calvoi (Bonaparte, 1991; MUCPv 54)

Alxasaurus elesitaiensis (Russell and Dong, 1993; Clark et al., 2004)

Anas platyrhynchus (AMNH 27496)

Anserimimus planinychus (Barsbold, 1988)

Apsaravis ukhaana (Norell and Clarke, 2001; Clarke and Norell, 2002; IGM 100/1017)

Archaeornithomimus asiaticus (Gilmore, 1933; Makovicky et al., 2004; AMNH FR 6558, AMNH FR 6565, AMNH FR 6566, AMNH FR 6567, AMNH FR 6568, AMNH FR 6569, AMNH FR 6570, AMNH FR 21626, AMNH FR 21627, AMNH FR 21786, AMNH FR 21787, AMNH FR 21788, AMNH FR 21789, AMNH FR

21790, AMNH FR 21791, AMNH FR 21797, AMNH FR 21896, AMNH FR 21802)

Archaeopteryx lithographica (de Beer, 1954; Ostrom, 1976b; Wellnhofer, 1974, 1993; Mayr et al., 2005; Norell et al., 2001; BMNH 37001)

Atrociraptor marshalli (Currie and Varricchio, 2004)

Avimimus portentosus (Kurzanov, 1981; Vickers-Rich et al., 2002; Osmólska et al., 2004)

Bambiraptor feinbergorum (Burnham et al., 2000; AMNH FR 30556)

Baptornis advenus (Marsh, 1877; AMNH FR 5101)

Buitreraptor gonzalezorum (Makovicky et al., 2005; MPCA-PV 245, MPCA-PV 238)

Byronosaurus jaffei (Norell et al., 2001; Makovicky et al., 2003; IGM 100/983, IGM 100/984)

Cathayornis yandica (Zhou et al., 1992; Zhou, 1995; Zhou and Hou, 2002; Hou, 1997)

Caudipteryx zoui (Ji et al., 1998; NGMC 97-9-A)

Chauna torquata (AMNH 3617)

Chirostenotes pergracilis (Currie and Russell, 1988; Sues, 1997; Osmólska et al., 2004)

Citipati osmolskae (Clark et al., 2001, 2002; IGM 100/978, IGM 100/979)

Coelurus fragilis (YPM 2010)

Compsognathus longipes (Bidar et al., 1972; Ostrom, 1978; Gishlick and Gauthier, 2007; Peyer, 2006; MNHN CNJ 79)

Conchoraptor gracilis (Barsbold, 1981, 1986; Kundrát and Janácek, 2007; IGM uncatalogued)

Concornis lacustris (Sanz et al., 1993; Sanz et al., 1995)

Confuciousornis sanctus (Chiappe et al., 1999; GMV 2131, IVPP V11370, IVPP V11374, IVPP V11375, IVPP V13171, IVPP V14385)

Crax yubra (AMNH 6272)

Crypturellus undullatus (AMNH 2751)

Daspletosaurus torsus (Russell, 1970; Currie, 2003)

Deinonychus antirrhopus (Maxwell and Witmer, 1996; Brinkman et al., 1998; Ostrom, 1969a,b, 1974, 1976a; YPM 5240, YPM 5205, AMNH FR 3015)

Dilong paradoxus (Xu et al., 2004; IVPP V14242, IVPP V14243, IVPP V11579)

Dromaeosaurus albertensis (Currie, 1995; AMNH FR 5356)

Erlikosaurus andrewsi (Perle, 1981; Clark et al., 1994, 2004; IGM 100/111)

Eotyrannus lengi (Hutt et al., 2001; MIWG 1997.550)

Gallimimus bullatus (Osmólska et al., 1972; Makovicky et al., 2004; Makovicky and Norell, 1988; IGM 100/1133)

Gallus gallus (AMNH 27820)

Garudimimus brevipes (Barsbold, 1981; Kobayashi and Barsbold, 2005)

Gobipteryx minuta (Elżanowski, 1976; Chiappe et al., 2001)

Gorgosaurus libratus (Norell et al., 2001; Currie, 2003; Russell, 1970; Lambe, 1914a, 1914b, 1917)

Graciliraptor lujiatunensis (Xu and Wang, 2004; IVPP V13474)

Harpymimus okladnikovi (Barsbold and Perle, 1984; Makovicky et al., 2004; Kobayashi and Barsbold, 2005)

Hesperornis regalis (Marsh, 1880)

Hongshanornis longicresta (Zhou and Zhang, 2005; IVPP V14533)

Huaxiagnathus orientalis (Hwang et al., 2004b; CAGS-IG02-301)

Iaceornis marshi (Clarke, 2004)

Ichthyornis dispar (Marsh, 1872, 1880; Clarke, 2004)

Incisivosaurus gauthieri (Xu et al., 2002b; IVPP V13326)

Ingenia yanshani (IGM 100/973)

Jeholornis prima (Ji et al., 2002a; Ji et al., 2003; Zhou and Zhang, 2002a, 2003a; IVPP V13353, IVPP V13274)

Jinfengopteryx elegans (Ji et al., 2005)

Jixiangornis orientalis (Ji et al., 2002b; CAGS uncatalogued)

Limenavis patagonicus (Clarke and Chiappe, 2001)

Liaoningornis longidigitris (Hou, 1996; Hou, 1997; Zhou and Hou, 2002)

Lithornis sp: (Houde, 1988; AMNH 21900, AMNH 21901, AMNH 21902, AMNH 21903)

Mahakala omnogovae (Turner et al., 2007b; IGM 100/1033)

Mei long (Xu and Norell, 2004; IVPP V12733)

Microraptor zhaoianus (Xu et al., 2000; Hwang et al., 2002; BPM 1 3-13; IVPP V12330, IVPP V12727, IVPP V13320, IVPP V13476, uncatalogued 1, uncatalogued 2, uncatalogued 3)

Microraptor "*gui"* (Xu et al., 2003; IVPP V13352)

Microvenator celer (Makovicky and Sues, 1998; AMNH FR 3041)

Mononykus olecranus (Perle et al., 1993, 1994; Chiappe et al., 2002; IGM 107/6)

Neuquenraptor argentinus (Novas and Pol, 2005; MCF PVPH-77)

Neuquenraptor sp (MUCPv uncatalogued)

Neuquenornis volans (Chiappe and Calvo, 1994; MUCPv 142)

Ornitholestes hermanni (Osborn, 1903, 1917; AMNH FR 619, AMNH FR 587)

Ornithomimus edmontonicus (Parks, 1926, 1928; Makovicky et al., 2004; AMNH FR 5201)

Oviraptor philoceratops (Osborn, 1924b; AMNH FR 6517)

Patagonykus puertai (Novas, 1997; MCF PVPH-37)

Patagopteryx deferrariisi (Chiappe, 2004; MACN N 11, MUCPv 48, MUCPv 207)

Pelecanomimus polyodon (Pérez-Moreno et al., 1994; Makovicky et al., 2004)

Proceratosaurus bradleyi (von Huene, 1926; BMNH R4860)

Pyroraptor olympius (Allain and Taquet, 2000; MNHN BO 001, MNHN BO 002, MNHN BO 003, MNHN BO 004, MNHN BO 005, MNHN BO 006, MNHN BO 007, MNHN BO 008, MNHN BO 009, MNHN BO 010, MNHN BO 012, MNHN BO 017, MNHN BO uncatalogued)

Rahonavis ostromi (Forster et al., 1998; UA 8656)

Rinchenia mongoliensis (Barsbold, 1986; Osmólska et al., 2004)

Sapeornis chaoyangensis (Zhou and Zhang, 2002b, 2003b; IVPP V13396, IVPP V15488)

Saurornithoides junior (Barsbold, 1974; Makovicky and Norell, 2004; Norell et al., in prep; IGM 100/1)

Saurornithoides mongoliensis (Osborn, 1924b; Makovicky and Norell, 2004; Norell et al., in prep; AMNH FR 6515)

Saurornitholestes langstoni (Sues, 1978; Norell et al., 2001; MOR 660; TMP 67.20.36; TMP 88.121.39; TMP 64.10.5)

Segnosaurus galbinensis (Perle, 1979, 1981; Clark et al., 2004)

Shanag ashile (Turner et al., 2007a; IGM 100/1119)

Shenzhousaurus orientalis (Ji et al., 2003; NGMC 97-4-002)

Shuvuuia deserti (Chiappe et al., 1998a; Chiappe et al., 2002; Suzuki et al., 2002; IGM 100/975, IGM 100/977, IGM 100/1001, IGM 100/1276, IGM 100/1304, IGM 100/1827, MPD 100/120)

Sinornithoides youngi (Russell and Dong, 1993; Currie and Dong, 2001; IVPP V9612)

Sinornithosaurus millenii (Xu et al., 1999; Xu and Wu, 2001)

Sinraptor dongi (Currie and Zhao, 1993)

Sinosauropteryx prima (Ji and Ji, 1998; Currie and Chen, 2001)

Sinovenator changii (Xu et al., 2002a; IVPP V9612)

Songlingornis linghensis (Hou, 1997)

Struthiomimus altus (Osborn, 1917; Makovicky et al., 2004; AMNH FR 5339, AMNH FR 5257)

Tarbosaurus bataar (Currie, 2003; IGM unnumbered?)

Troodon formosus (Currie, 1985; Currie and Zhao, 1993; Norell et al., 2001; Makovicky et al., 2003)

Tsaagan mangas (Norell et al., 2006; IGM 100/1015)

Tyrannosaurus rex (Brochu, 2003; Currie, 2003; AMNH FR 5027; FMNH PR 2081)

Undescribed troodontid 1 (“EK Troodontid” IGM 100/44)

Undescribed troodontid 2 (IGM 100/1128)

Undescribed troodontid 3 (IGM 100/1323)

Unenlagia comahuensis (Novas and Puerta, 1997; Novas, 2004; MCF PVPH-78)

Unenlagia paynemili (Calvo et al., 2004; MUCPv 343, 349, 409, 415, 416)

Utahraptor ostrommaysorum (Kirkland et al., 1993; Britt et al., 2001; CEU 184v.400/CEUM 1430, CEU 184v.86/CEUM 1456, CEU 184v.42/CEUM 1112, CEU 184v.1145/CEUM 39596, CEU 184v.300/CEUM 1370, CEU 184v.215/CEUM 1285, CEU 184v.457/CEUM 4023, CEU 184v.1010/CEUM 5440, CEU 184v.667/CEUM 3538, CEU 184v.1072/CEUM 8586, CEU 184v.180/CEUM 1250, CEU 184v.260/CEUM 1330, CEU 184v.792/CEUM 3666, CEU 184v.951/CEUM 5372, CEU 184v.883/CEUM 3928, BYU VP 14569, BYU VP 14614, BYU VP uncatalogued premaxilla, BYU VP uncatalogued coracoid—field number 3269, BYU VP 14389, BYU VP 14024, BYU VP 15634, BYU VP 14627, BYU VP 9941, BYU VP 15209, BYU VP 18118, BYU VP 11056, BYU VP 14287, BYU VP 18085, BYU VP 11300, BYU VP 18086, BYU VP 18049, BYU VP 18073, BYU VP 9438, BYU VP 14701, BYU VP 15484, BYU VP 14146, BYU VP 18048, BYU VP 18087, BYU VP 15690, BYU VP 15465, BYU VP 14281, BYU VP 15417, BYU VP 18079, BYU VP 15416, BYU VP 14567, BYU VP 10748, BYU VP 14500, BYU VP 14776, BYU VP 15204, BYU VP 14372)

Velociraptor mongoliensis (Barsbold and Osmolska, 1999; AMNH FR 6515, IGM 100/24, IGM 100/25, IGM 100/976, IGM 100/982, IGM 100/985, PIN 3143/8, ZPAL MgD-8/97)

Vorona berivotrensis (Forster et al., 1996; Forster et al., 2002; UA 8651, FMNH PA 715, FMNH PA 717)

Yanornis martini (Zhou and Zhang, 2001; IVPP V12444)

Yixianornis grabaui (Clarke et al., 2006; Zhou and Zhang, 2001; IVPP V12631)

APPENDIX 2: INSTITUTION LIST

AMNH	American Museum of Natural History, New York, NY, USA
BMNH	The Natural History Museum, London, UK
BPM	Beipiao Paleontological Museum, Liaoning province, China
BYU VP	Brigham Young University, Provo, Utah, USA
CEUM	College of Eastern Utah, Price, Utah, USA
FMNH	Field Museum of Natural History, Chicago, IL, USA
IGM	Mongolian Institute of Geology, Ulaan Bataar, Mongolia
IVPP	Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China
GMV	National Geological Museum of China, Beijing, China
MACN	Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina
MCF	Museo Carmen Funes, Plaza Huincul, Neuquén Province, Argentina
MDE	Musée des Dinosaures, Espéraza, France
MIWG	Museum of the Isle Wight Geology, Sandown, Isle of Wight, UK
MNHN	Muséum National d'Histoire Naturelle, Paris, France
MOR	Museum of the Rockies, Bozeman, MT, USA
MOZ	Museo Profesor J. Olsacher, Zapala, Argentina
MPCA	Museo Carlos Ameghino, Cipolletti, Río Negro Province, Argentina
NGMC	National Geological Museum of China, Beijing, China
PIN	Paleontological Institute Moscow, Russia
OMNH	Oklahoma Museum of Natural History, Norman, OK, USA
SMP	The State Museum of Pennsylvania, Harrisburg, PA, USA
TMP	Royal Tyrell Museum of Paleontology, Alberta, Canada

UA University of Antananarivo, Madagascar

UMNH Utah Museum of Natural History, Salt Lake City, UT, USA

WDC Wyoming Dinosaur Center, Thermopolis, WY, USA

YPM Yale Peabody Museum, New Haven, CT, USA

ZPAL Instytut Paleobiologii PAN, Warszawa, Poland

APPENDIX 3: CHARACTER LIST

Character 1: Vaned feathers on forelimb

0: symmetric

1: asymmetric

The barbs on opposite sides of the rachis differ in length; in extant birds, the barbs on the leading edge of flight feathers are shorter than those on the trailing edge. *Sinosauropteryx prima*, *Caudipteryx zoui*, , and *Sinornithosaurus millenii* are state 0. The derived state is present in *Microraptor zhaoianus and Archaeopteryx lithographica*, *Confuciusornis sanctus* and all avialans that preserve integumentary structures. The derived state is synapomorphic for Avialae and autapomorphic for *Microraptor zhaoianus*.

Character 2: Orbit shape

0: round in lateral or dorsolateral view

1: dorsoventrally elongate

It is improbable that the eye occupied the entire orbit of those taxa in which it is keyhole shaped. Only *Allosaurus fragilis*, *Sinraptor dongi*, *Tyrannosaurus rex* and *Albertosaurus sarcophagus* have the derived, dorsoventrally elongate orbit (state 1).

Character 3: Anterior process of postorbital

0: projects into orbit

1: does not project into orbit

In the current context, an anterior process of the postorbital that projects into the orbit (state 0) is synapomorphic for tyrannosaurids. The feature however is not present in *Dilong paradoxus*.

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

The derived state appears to be present in all maniraptorans that preserve a postorbital. Ornithomimosaurs, derived tyrannosaurs and *Ornitholestes hermanni* possess the primitive straight anterior process on the postorbital, as do *Allosaurus fragilis* and *Sinraptor dongi*. Complicating this distribution however, is the presence of the derived condition in the alvarezsaurid *Shuvuuia deserti*, although it is unknown in *Patagonykus puertai*, and *Alvarezsaurus calvoi*.

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

The derived state for this character is synapomorphic for a derived clade of Ornithomimosaurs including *Struthiomimus altus*, *Gallimimus bullatus*, and *Ornithomimus edmonticus*. However, this character is unknown for other Ornithomimosaurs and therefore may be present more broadly in the group.

Character 6: Otosphenoidal crest position:

0: vertical on basisphenoid and prootic, and does not border an enlarged pneumatic recess

1: well developed, crescent shaped, thin crest forms anterior edge of enlarged pneumatic recess

This structure forms the anterior, and most distinct, border of the "lateral depression" of the middle ear region (Currie, 1985; Currie and Zhao, 1993) of derived troodontids and some extant avians. A well developed crescent-shaped otosphenoidal crest forming the anterior edge of an enlarged pneumatic recess is present in *Chirostenotes gracilis*, *Shuvuuia deserti* (unknown in other alvarezsaurs), *Troodon formosus*, *Saurornithoides mongoliensis* and *Saurornithoides junior*, *Byronosaurus jaffei*, and *Sinornithoides youngi*. It is not present in the basal troodontids *Mei long* and *Sinovenator changii*.

Character 7: Crista interfenestralis location

0: confluent with lateral surface of prootic and opisthotic

1: distinctly depressed within middle ear opening

The distribution of character states for this character is poorly known. Only 11 taxa (~24%) can be coded for this character. *Mononykus olecranus*, *Shuvuuia deserti, Archaeopteryx lithographica,*

Byronosaurus jaffei, Sinovenator changii and the Early Cretaceous troodontid IGM 100/44 possess a crista interfenestralis confluent with the lateral surface of the prootic and opisthotic (state 0). *Troodon formosus*, *Tsaagan mangas*, *Velociraptor mongoliensis*, *Dromaeosaurus albertensis* and *Citipati osmolskae* exhibit a distinctly depressed crista interfenestralis (state 1). Currently the character distribution within the outgroup is unknown.

Character 8: Subotic recess (pneumatic fossa ventral to fenestra ovalis)

0: absent

1: present

A subotic recess is primitive absent in theropods. *Struthiomimus altus*, *Gallimimus bullatus*, *Ornithomimus edmonticus*, *Troodon formosus*, *Saurornithoides mongoliensis*, *Saurornithoides junior*, *Byronosaurus jaffei*, and the Early Cretaceous troodontid IGM 100/44 possess a subotic recess. This was used by some authors to suggest a sister group relationship between troodontids and ornithomimosaurs. It is clear that the structures in the two groups are convergent given that basal troodontids such as *Sinovenator changii* lack a subotic recess.

Character 9: Basisphenoid recess

0: present between basisphenoid and basioccipital

1: entirely within basisphenoid

2: absent

A basisphenoid recess appears to only be absent in troodontids (e.g., *Troodon formosus, Saurornithoides junior*, *Sinovenator changii*, and EK troodontid IGM 100/44) and the therizinosaur *Erlikosaurus andrewsi* (although it is unknown in *Segnosaurus galbinensis* and *Alxasaurus elesitaiensis*). The outgroup exhibit state 0—a recess present between the basioccipital and basisphenoid. State 0 is also present in the tyrannosauroids *Dilong paradoxus* and *Albertosaurus libratus*, the oviraptorosaurs *Citipati osmolskae* and *Chirostenotes pergracilis*, the dromaeosaurids *Tsaagan mangas, Velociraptor mongoliensis*, and *Dromaeosaurus albertensis*, the alvarezsaurid *Shuvuuia deserti*, and in *Ornitholestes hermanni*. Therefore it appears that state 0 is the primitive condition for coelurosaurs and that a basisphenoid recess entirely within the basisphenoid was independently derived at least twice within coelurosaurs—once in oviraptorosaurs (e.g., *Incisivosaurus gauthieri*, *Avimimus portentosus*, *Struthiomimus altus*, *Gallimimus*

bullatus, and *Ornithomimus edmonticus*) and once in Tyrannosaur rex. Complicating understanding the distribution of this character is the lack of data for compsognathids and limited sampling in tyrannosaurids. For instance, with *Albertosaurus libratus* and *Dilong paradoxus* both showing state 0, it is unclear if state 1 is autapomorphic for *Tyrannosaurus rex* or if it diagnoses a more restricted clade of tyrannosaurids.

Character 10: Posterior opening of basisphenoid recess

0: single

1: divided into two small, circular foramina by a thin bar of bone

A posteriorly divided basisphenoid recess is present in *Citipati osmolskae*, *Chirostenotes pergracilis*, the dromaeosaurids *Tsaagan mangas*, *Deinonychus antirrhopus*, and *Velociraptor mongoliensis*, and the tyrannosauroid *Tyrannosaurus rex*.

Character 11: Base of cultriform process (parasphenoid rostrum)

0: not highly pneumatized

1: expanded and pneumatic (parasphenoid bulla present

A parasphenoid bulla is present in all ornithomimosaurs that have braincases preserved (e.g., *Gallimimus bullatus*, *Garudimimus brevipes*, and *Pelecanimimus polydon*) as well as in the troodontids *Troodon formosus*, *Saurornithoides mongoliensis*, and *Saurornithoides junior*. This was used by some authors to suggest a sister group relationship between troodontids and ornithomimosaurs. However, the absence of a parasphenoid bulla in the basal troodontid demonstrates that the character evolved independently in troodontids.

Character 12: Basipterygoid processes project [*MODIFIED FROM TWiG c12*]

0: ventral or anteroventrally projecting

1: lateroventrally projecting

2: laterally

Lateroventrally projecting basipterygoid processes are known in *Avimimus portentosus*, the ornithomimosaurs *Gallimimus bullatus*, *Garudimimus brevipes*, and *Ornithomimus edmonticus*, and in the derived troodontids *Troodon formosus*, *Saurornithoides mongoliensis*, *Saurornithoides junior*, and *Byronosaurus jaffei*. A third state was added to score the condition present in derived avialans.

Character 13: Basipterygoid processes

0: well developed, extending as a distinct process from the base of the basisphenoid

1: processes abbreviated or absent (1).

Abbreviated basipterygoid processes (state 1) are present in oviraptorosaurs (e.g., *Citipati osmolskae*, *Oviraptor philoceratops*, *Incisivosaurus gauthieri*, *Chirostenotes pergracilis*, and *Avimimus portentosus*) and in the therizinosaur *Erlikosaurus andrewsi*, however this character is unknown in *Alxasaurus elesitaiensis*.

Character 14: Basipterygoid processes

0: solid

1: processes hollow

Hollow basipterygoid processes (state 1) are present in *Chirostenotes pergracilis*, the ornithomimosaurs *Gallimimus bullatus*, *Garudimimus brevipes*, and *Ornithomimus edmonticus*, as well as in the derived troodontids *Troodon formosus, Saurornithoides mongoliensis, Saurornithoides junior, and Byronosaurus jaffei.*

Character 15: Basipterygoid recesses on dorsolateral surfaces of basipterygoid processes

0: absent

1: present

Character 16: 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

The dorsal tympanic recess referred to here is the depression anterodorsal to the middle ear on the opisthotic, not the recess dorsal to the crista interfenestralis within the middle ear as seen in *Archaeopteryx lithographica, Shuvuuia deserti* and Aves.

Character 17: Accessory tympanic recess dorsal to crista interfenestralis ORDERED

0: absent

1: small pocket present

2: extensive with indirect pneumatization

According to (Witmer, 1990), this structure may be an extension from the caudal tympanic recess, although it has been interpreted as the main part of the caudal tympanic recess by some previous authors. A small pocket (state 1) is located dorsal to the crista interfenestralis in *Mononykus olecranus*, *Shuvuuia deserti*, *Archaeopteryx lithographica*, *Byronosaurus jaffei*, and *Sinovenator changii*. *Citipati osmolskae* shows state 2, extensive indirect pneumatization. An accessory recess is known to be absent in *Allosaurus fragilis, Sinraptor dongi, Dromaeosaurus albertensis, Velociraptor mongoliensis, Tsaagan mangas, Struthiomimus altus, Gallimimus bullatus, Ornithomimus edmonticus, Tyrannosaurus rex, and Troodon formosus*,

Character 18: 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 19: Exits of C. N. X-XII

0: flush with surface of exoccipital

1: located together in a bowl-like depression

Character 20: 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 21: Internarial bar shape

0: rounded

1: flat

Character 22: Crenulated margin on buccal edge of premaxilla

0: absent

1: present

Character 23: Position of caudal margin of naris (Chiappe et al., 1998b)

0: farther rostral than

1: nearly reaching or overlapping the rostral border of the antorbital fossa

Character 24: Premaxillary symphysis shape

0: acute, V-shaped

1: rounded, U-shaped

Character 25: Secondary palate [Redefined by MAE 05.]

0: short

1: long, with extensive palatal shelves on maxilla

Character 26: Palatal shelf of maxilla

0: flat

1: with midline ventral 'tooth-like' projection

Character 27: Pronounced, round accessory antorbital fenestra [*MODIFIED FROM TWiG*] 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

A small fenestra, variously termed the accessory antorbital fenestra or maxillary fenestra, penetrates the medial wall of the antorbital fossa anterior to the antorbital fenestra in a variety of coelurosaurs and other theropods. This character was modified from the TWG character following Currie and Varricchio, 2004: char. 22.

Character 28: Accessory antorbital fossa

0: situated at rostral border of antorbital fossa

1: situated posterior to rostral border of fossa

Character 29: Tertiary antorbital fenestra (fenestra promaxillaris)

0: absent

1: present

Character 30: Narial region

0: apneumatic or poorly pneumatized (0)

1: with extensive pneumatic fossae, especially along posterodorsal rim of naris

Character 31: Jugal and postorbital

0: contribute equally to postorbital bar

1: ascending process of jugal reduced and descending process of postorbital ventrally elongate

Character 32: Jugal height beneath lower temporal fenestra

0: tall, twice or more as tall dorsoventrally as it is wide transversely

1: rod-like

Character 33: Jugal, pneumatic recess in posteroventral corner of antorbital fossa

0: present

1: absent

Character 34: Medial jugal foramen

0: present on medial surface ventral to postorbital bar

1: absent

Character 35: Quadratojugal shape

0: without horizontal process posterior to ascending process (reversed "L" shape)

1: with process (i.e., inverted 'T' or 'Y' shape)

Character 36: Jugal and quadratojugal

0: separate

1: quadratojugal and jugal fused and not distinguishable from one another

Character 37: Supraorbital crests on lacrimal in adult individuals

0: absent

1: dorsal crest above orbit

2: lateral expansion anterior and dorsal to orbit

Supraorbital crests are variably present within Theropoda, and is present in immediate coelurosaur outgroups such as *Allosaurus* and *Sinraptor*. Among coelurosaurs that are primarily found among basal members such as tyrannosauroids like *Dilong*, *Eotyrannus*, and derived tyrannosaurids like *Daspletosaurus* and *Tyrannosaurus*. An unambiguous synapomorphy of all troodontids examined is the third state of this character; a large lateral expansion anterior and dorsal to the orbit. This expansion in troodontids takes the

form of a large triangular lamina. The small angle of the triangle is present anterior to the preorbital bar whereas the widest portion of the crest is posteriorly above the anterior margin of the orbit. Dorsoventrally this crest is very thin and originates from the very dorsal-most surface of the lacrimal.

Character 38: Enlarged foramen or foramina opening laterally at the angle of the lacrimal above antorbital fenestra

0: absent

1: present

Character 39: Lacrimal anterodorsal process

0: absent (inverted 'L' shaped)

1: 'T' shaped in lateral view

2: anterodorsal process much longer than posterior process

Character 40: Prefrontal ORDERED

0: large, dorsal exposure similar to that of lacrimal

1: greatly reduced in size

2: absent

Character 41: Frontals

0: narrow anteriorly as a wedge between nasals

1: end abruptly anteriorly, suture with nasal transversely oriented

Character 42: Anterior emargination of supratemporal fossa on frontal [Currie, 1995]

0: straight or slightly curved

1: strongly sinusoidal and reaching onto postorbital process (1)

Character 43: Frontal postorbital process (dorsal view) [Currie, 1995]

0: smooth transition from orbital margin

1: sharply demarcated from orbital margin

Character 44: Frontal edge [Currie, 1995]

0: smooth in region of lacrimal suture

1: edge notched

Character 45: 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 46: Parietals

0:separate

1: fused

Character 47: Descending process of squamosal

0: parallels quadrate shaft

1: nearly perpendicular to quadrate shaft

Character 48: Descending process of squamosal

0: contacts quadratojugal

1: does not contact quadratojugal

Character 49: Posterolateral shelf on squamosal overhanging quadrate head [Currie, 1995]

0: absent

1: present

EXCLUDED Character 50: Dorsal process of quadrate

0: single headed

1: with two distinct heads, a lateral one contacting the squamosal and a medial head contacting the braincase

This character was excluded in favor of two separate characters that I feel more clearly and explicitly capture the morphology described by C50. Namely this splitting of the character is to draw distinction between whether or not the quadrate is single or double headed and whether or not the quadrate articulates just with the squamosal or with the lateral braincase wall as well. As taxon sampling became more dense within paravians it became apparent that these two states are not co-dependent. Character 350 and 351 replace this character.

Character 51: Quadrate orientation

0: vertical

1: strongly inclined anteroventrally so that distal end lies far forward of proximal end

EXCLUDED Character 52: Quadrate [Molnar, 1985]

0: solid

1: hollow, with foramen on posterior surface

This character was excluded in favor of characters 353, 354, and 355, which capture a much wider range of morphologies associated with quadrate pneumaticity.

Character 53: 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 54: Foramen magnum shape [Makovicky and Sues, 1998]

0: subcircular, slightly wider than tall

1: oval, taller than wide

Character 55: Occipital condyle

0: without constricted neck

1: subspherical with constricted neck

Character 56: Paroccipital process

0: elongate and slender, with dorsal and ventral edges nearly parallel

1: process short, deep with convex distal end

Character 57: Paroccipital process

0: straight, projects laterally or posterolaterally

1: distal end curves ventrally, pendant

Character 58: Paroccipital process [Currie, 1995]

0: with straight dorsal edge

1: with dorsal edge twisted rostrolaterally at distal end

Character 59: Ectopterygoid

0: with constricted opening into ventral fossa

1: with open ventral fossa in the main body of the element

Character 60: Dorsal recess on ectopterygoid

0: absent

1: present

Character 61: Flange of pterygoid

0: well developed

1: reduced in size or absent

A reduced or absent pterygoid flange occurs in a number of coelurosaur groups. Avialans including *Archaeopteryx* have a reduced or absent flange as do the therizinosauroid *Erlikosaurus andrewsi*, the alvarezsaurid *Shuvuuia deserti* and all oviraptorosaurs where the flange can be observed (e.g., *Citipati osmolskae*, *Oviraptor philoceratops*, *Incisivosaurus gauthieri*).

Character 62: Palatine and ectopterygoid [Currie, 1995]

0: separated by pterygoid

1: contact

Character 63: Palatine shape [Elzanowski and Wellnhofer, 1996]

0: tetraradiate, with jugal process

1: palatine triradiate, jugal process absent

Character 64: 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 65: Symphyseal region of dentary

0: broad and straight, paralleling lateral margin

1: medially recurved slightly

2: strongly recurved medially

Character 66: Dentary symphyseal region

0: in line with main part of buccal edge

1: symphyseal end downturned

Character 67: Mandible

0: without coronoid prominence

1: with coronoid prominence

Character 68: 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 69: Labial face of dentary [Russell and Dong, 1993]

0: flat

1: with lateral ridge and inset tooth row

Character 70: Dentary shape [Currie, 1995]

0: subtriangular in lateral view

1: with subparallel dorsal and ventral edges

Character 71: Nutrient foramina on external surface of dentary [Currie, 1987]

0: superficial

1: lie within deep groove

Character 72: External mandibular fenestra shape

0: oval

1: subdivided by a spinous rostral process of the surangular

This is a derived oviraptorid synapomorphy present in *Conchoraptor gracilis*, *Oviraptor philoceratops*, *Citipati osmolskae*, and *Ingenia yanshani*.

Character 73: Internal mandibular fenestra [Currie, 1995]

0: small and slit-like

1: large and rounded

Character 74: Foramen in lateral surface of surangular rostral to mandibular articulation

0: absent

1: present

Character 75: 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 76: Coronoid ossification ORDERED

0: large

1: only a thin splint

2: absent

Character 77: Articular

0: without elongate, slender medial, posteromedial, or mediodorsal process from retroarticular process

1: with process

Character 78: Retroarticular process

0: short, stout

1: elongate and slender

Character 79: 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 80: Premaxilla

0: toothed

1: edentulous

Character 81: 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 82: Maxilla

0: toothed

1: edentulous

Character 83: Maxillary and dentary teeth

0: serrated

1: some without serrations anteriorly (except at base in *S. mongoliensis*)

2: all without serrations

Character 84: Dentary and maxillary teeth

0: large

1: small (25-30 in dentary)

Character 85: Dentary teeth [Currie, 1987]

0: in separate alveoli

1: set in open groove

Character 86: Serration denticles [Farlow et al., 1991 quantify this difference]

0: large

1: small

Character 87: 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 88: Teeth

0: constricted between root and crown

1: root and crown confluent

Character 89: Dentary teeth

0: evenly spaced

1: anterior dentary teeth smaller, more numerous, and more closely appressed than those in middle of tooth row

Character 90: Dentaries

0: lack distinct interdental plates

1: with interdental plates medially between teeth (1).

Currie (1995) suggests the interdental plates of dromaeosaurids are present but fused to the medial surface of the dentary, whereas they are absent in troodontids. In the absence of a definitive, non-destructive method for parsing between fusion/ loss we do not recognize this distinction, and code all taxa that lack distinct interdental plates with State 1.

Character 91: In cross section, premaxillary tooth crowns

0: sub-oval to sub-circular

1: asymmetrical (D-shaped in cross section) with flat lingual surface (1)

Character 92: Number of cervical vertebrae

0: ≤10 (0)

1: 12 or more

Character 93: Axial epipophyses

0: absent or poorly developed, not extending past posterior rim of postzygapophyses

1: large and posteriorly directed, extend beyond postzygapophyses

This character is modified from Gauthier (1986) character 69 and Makovicky and Sues (1998) character 30. Rauhut (2003) character 92 also pertains to axial epipophyseal morphology. Rauhut (2003) has a three-state ordered character describing the epiphyses on the axis as absent, present as a small ridge, or present and strongly pronounced, overhanging the postzygapophyses. Rauhut (2003) considers *Herrerasaurus*, *Monolophosaurus*, *Microvenator*, *Avimimus*, and Ornithomimosauria as possessing small ridge-like epipophyses (state 1). Large and posteriorly directed epipophyses that extend beyond the postzygapophysis are present in *Allosaurus fragilis* and Sinraptor dongi. This character is reversed (state 0) at the base of all Coelurosauria more derived than Tyrannosauroidea. In more derived coelurosaurs, large epipophyses extending beyond the postzygapophyses is recovered as a paravian synapomorphy although it is reversed (state 0) in troodontids more derived than *Sinovenator changii* + *Mei long*. This optimization is based on the presence of state 0 in EK troodontid and *Byronosaurus jaffei*. The condition is unknown in *Troodon*, *Saurornithoides*, and *Sinornithoides*.

Character 94: Axial neural spine

0: flared transversely

1: compressed mediolaterally

A mediolaterally compressed axial neural spine is present in all coelurosaurs for which this element is known except *Tyrannosaurus rex*, *Albertosaurus libratus*, and *Archaeornithomimus asiaticus*. The spine is flared transversely in these taxa as well as in the outgroups *Allosaurus* and *Sinraptor*.

Character 95: Epipophyses of cervical vertebrae

0: placed distally on postzygapophyses, above postzygapophyseal facets

1: placed proximally, proximal to postzygapophyseal facets

As currently scored, only seven taxa (*Shuvuuia deserti*, *Microvenator celer*, *Avimimus portentous*, *Gallimimus bullatus*, *Troodon formosus*, *Sinovenator changii*, and *Citipati osmolskae*) are known to possess a proximally placed epipophysis (state 1). However, given the distribution across the tree it is presently most parsimonious to interpret this character state a synapomorphic for all coelurosaurs more derived than *Tyrannosaurus rex* + *Albertosaurus libratus*. The character is revered to the more widespread theropod condition (state 0; distally placed above the postzygapophyses) in Compsognathids, dromaeosaurids, and *Mei long*.

Character 96: Anterior cervical centra

0: level with or shorter than posterior extent of neural arch

1: centra extending beyond posterior limit of neural arch

In most basal theropods (e.g., *Coelophysis*, *Dilophosaurus* (UCMP 37302) *Allosaurus fragilis*, *Tyrannosaurus rex* (FMNH PR2081), the anterior cervical centra does not extent beyond the posterior limit of the neural arch. An anterior cervical centra that extends beyond the posterior limit of the neural arch (state 1) is synapomorphic for all coelurosaurs more derived than Tyrannosauroidea. A reversal to anterior cervical centra that are level or shorter than the posterior extent of the neural arch (state 0) is present in *Avimimus portentosus* and is synapomorphic for dromaeosauridae (known in *Microraptor zhaoianus*, *Tsaagan mangas*, *Saurornitholestes langstoni*, *Velociraptor mongoliensis*, and *Deinonychus antirrhopus*).

Character 97: Carotid process on posterior cervical vertebrae

0: absent

1: present

This is a very “avian” characteristic. Carotid processes are present in *Buitreraptor gonzalezorum*, Mei long, *Sinornithoides youngi*, *Troodon formosus*, *Avimimus portentosus*, *Shuvuuia deserti*, *Mononykus* olecranus, and *Microraptor zhaoianus*; although it is unknown in *Archaeopteryx lithographica* and *Confuciusornis sanctus*.

Character 98: Anterior cervical centra [Gauthier, 1986]

0: subcircular or square in anterior view

1: distinctly wider than high, kidney shaped

Character 99: 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 100: Cervical centra [Gauthier, 1986]

0: with one pair of pneumatic openings

1: with two pairs of pneumatic openings

Character 101: Cervical and anterior trunk vertebrae [MODIFIED]

0: amphiplatyan

1: opisthocoelous

2: at least partially heterocoelous

Character 102: Anterior trunk vertebrae [Gauthier, 1986]

0: without prominent hypapophyses

1: with large hypapophyses

Character 103: Parapophyses of posterior trunk vertebrae [Norell and Makovicky, 1999]

0: flush with neural arch

1: distinctly projected on pedicels

Character 104: Hyposphene-hypantrum articulations in trunk vertebrae

0: absent

1: present

Character 105: Zygapophyses of trunk vertebrae

0: abutting one another above neural canal, opposite hyposphenes meet to form lamina

1: zygapophyses placed lateral to neural canal and separated by groove for interspinous ligaments, hyposphenes separated

Character 106: Cervical vertebrae pneumaticity [MODIFIED to refer to just the cervicals]

0: absent

1: present

Character 107: Transverse processes of anterior dorsal vertebrae

0: long and thin

1: short, wide, and only slightly inclined

Character 108: Neural spines of dorsal vertebrae

0: not expanded distally

1: expanded to form ‘spine table’

Character 109: Scars for interspinous ligaments

0: terminate at apex of neural spine in dorsal vertebrae

1: terminate below apex of neural spine

Character 110: Number of sacral vertebrae ORDERED

0: 5 or less

1: 6

2: 7

3: 8

4: 9

5: 10

6: 11 or more

7: 15 or more

This character has been modified to include the character states of CEA 06 62 to score for the additional derived morphology in derived avialans.

Character 111: Sacral vertebrae

0: with unfused zygapophyses

1: with fused zygapophyses forming a sinuous ridge in dorsal view

Character 112: 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

Note that in *Alvarezsaurus calvoi* it is only the fifth sacral that is keeled, unlike other alvarezsaurids (Novas, 1997).

Character 113: Pleurocoels ORDERED

0: absent on sacral vertebrae

1: present on anterior sacrals only

2: present on all sacrals

Character 114: Last sacral centrum

0: with flat posterior articulation surface

1: convex articulation surface

Character 115: 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 116: Transition point in caudal series

0: begins distal to the 10th caudal vertebra

1: between the 7th and 10th caudal vertebra

2: or proximal to the 7th caudal vertebra

New state added by MAE 05. A second state for having the transition point proximal to the 6th vertebra was added specifically to test the purported avialan relationships of *Rahonavis.*

Character 117: Anterior caudal centra [modified from Gauthier, 1986]

0: tall, oval in cross section

1: with box-like centra in caudals I-V

2: anterior caudal centra laterally compressed with ventral keel

Character 118: 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 119: 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 120: Prezygapophyses of distal caudal vertebrae

0: between 1/3 and whole 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

State 3 was added from CEA 06 67 in order to score the condition present in *Ichthyornis dispar*. Currently state 3 is autapomorphic for that taxon.

Character 121: Number of caudal vertebra [MODIFIED from Turner et al., 2007b]

0: more than 40 caudal vertebrae

1: 25-40 caudal vertebrae

2: no more than 25 caudal vertebrae

3: very short, less than 8 free caudal vertebrae

This character has been reworded to incorporate CEA 06 64.1, which scores for the tail morphology of derived avialans.

Character 122: Proximal end of chevrons of proximal caudals

0: short anteroposteriorly, shaft cylindrical

1: proximal end elongate anteroposteriorly, flattened and plate-like

Character 123: Distal caudal chevrons

0: simple

1: anteriorly bifurcate

2: bifurcate at both ends

Character 124: Shaft of cervical ribs

0: slender and longer than vertebra to which they articulate

1: broad and shorter than vertebra

Character 125: Ossified uncinate processes ORDERED

0: absent

1: present and unfused to ribs

2: fused to ribs

This character was modified to include a third state based on CEA 07 70.2 in order to score for the morphology present in many extant avians.

Character 126: Ossified ventral (sternal) rib segments

0: absent

1: present

Character 127: Lateral gastral segment

0: shorter than medial one in each arch

1: distal segment longer than proximal segment

Character 128: Ossified sternal plates

0: separate in adults

1: fused

Character 129: Sternum

0: without distinct lateral xiphoid process posterior to costal margin

1: with lateral xiphoid process

Character 130: Anterior edge of sternum

0: grooved for reception of coracoids

1: sternum without grooves

Character 131: 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 132: Hypocledium on furcula ORDERED

0: absent

1: present as tubercle

2: present as an elongate process

The hypocledium is a process extending from the ventral midline of the furcula, and is attached to the sternum by a ligament in extant birds. Although a number of taxa such as advanced tyrannosaurids display a slight midline ridge (Makovicky and Currie, 1998) this is considered state 0 here. Only a full

process as occurs in e.g. *Oviraptor* is considered state 1 in our analysis. MODIFIED. State 1 was divided into two distinct states scoring for the incipient form of a hypocledium as is present in some basal coelurosaurs as well as derived avialans. This modification follows CEA 06 82.

Character 133: Acromion margin of scapula

0: continuous with blade

1: anterior edge laterally everted

Character 134: Posterolateral surface of coracoid ventral to glenoid fossa

0: unexpanded

1: posterolateral edge of coracoid expanded to form triangular subglenoid fossa bounded laterally by enlarged coracoid tuber

Character 135: Scapula and coracoid

0: separate

1: fused into scapulacoracoid

Character 136: 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 strut-like

This character was modified following CEA 06 89. A fourth state was added to score the derived condition in most avialans.

Character 137: Scapula and coracoid

0: form a continuous arc in posterior and anterior views

1: coracoid inflected medially, scapulocoracoid 'L' shaped in lateral view

Character 138: Glenoid fossa faces

0: posteriorly or posterolaterally

1: laterally

Character 139: Scapula length

0: longer than humerus

1: humerus longer than scapula

Character 140: 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

(original wording): Deltopectoral crest large and distinct, proximal end of humerus quadrangular in anterior view (0) or deltopectoral crest less pronounced, forming an arc rather than being quadrangular (1) or deltopectoral crest very weakly developed, proximal end of humerus with rounded edges (2) or deltopectoral crest extremely long and rectangular (3) or proximal end of humerus extremely broad, triangular in anterior view (4). In the present context old state 4 was autapomorphic for *Confuciusornis*.

Character 141: 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 142: Olecranon process

0: weakly developed

1: distinct and large

Character 143: Distal articular surface of ulna (dorsal condyle and dorsal trochlea in birds)

0: flat

1: convex, semilunate surface (1).

MODIFIED. Wording changed slightly following CEA 06.

Character 144: 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 145: Lateral proximal carpal (ulnare?)

0: quadrangular

1: triangular in proximal view

The homology of the carpal elements of coelurosaurs is unclear (see, e.g., (Padian and Chiappe, 1998)), but the large, triangular lateral element of some taxa most likely corresponds to the lateral proximal carpal of basal tetanurans.

Character 146: 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

In the absence of ontogenetic data, it is not possible to determine whether the single large semilunate carpal of birds and many other coelurosaurs is formed by fusion of the two distal carpals or is, instead, an enlarged distal carpal 1 or 2.

EXCLUDED Character 147: Distal carpals not fused to metacarpals (0) or fused to metacarpals, forming carpometacarpus (1).

This character is excluded in favor of C455.

Character 148: 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

In modern birds, the semilunate covers MC II and MC III. This character was modified to include a fourth state for the derived avialan condition in which the semilunate carpal does not cover any portion of metacarpal 1.

Character 149: 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 150: Third manual digit

0: present, phalanges present

1: reduced to no more than metacarpal splint

Character 151: 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

A fourth state was added to this character in order to score for the absence of unguals in derived avialans.

Character 152: Unguals on all digits

0: generally similar in size

1: digit I bearing large ungual and unguals of other digits distinctly smaller

Character 153: Proximodorsal 'lip' on some manual unguals - a transverse ridge immediately dorsal to the articulating surface

0: absent

1: present

Character 154: Ventral edge of anterior ala of ilium

0: straight or gently curved

1: ventral edge with shallow, obtuse process

2: process strongly hooked

Character 155: 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

MODIFIED. A third character state was added to score the ilium morphology seen in *Hesperornis*.

Character 156: 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

MODIFIED. A fourth character state was added to include the tyrannosaurid morphology as noted by R 03 173.

Character 157: 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 158: Postacetabular ala of ilium in lateral view

0: squared

1: acuminate

Character 159: Postacetabular blades of ilia in dorsal view

0: subparallel

1: diverge posteriorly

Character 160: Tuber along dorsal edge of ilium, dorsal or slightly posterior to acetabulum

0: absent

1: present

Novas (2004) noted the presence of this tuber on the ilia of *Saurornitholestes langstoni* (MOR 660)*, Deinonychus antirrhopus* (AMNH 30115, MCZ 4317), and *Velociraptor mongoliensis* (IGM 100/985), *Unenlagia comahuensis*, *Archaeopteryx lithographica* (Berlin specimen), Enantiornithes (Walker, 1981), *Confuciusornis sanctus* (Chiappe et al., 1999) and *Rahonavis ostromi*. This tuber is considered homologous to the processus supratrochantericus of birds. It is associated with an oblique ridge that runs from the dorsal surface of the acetabulum to the supratrochanteric process. Novas (2004) indicated that, according to Baumel and Witmer (1993), this ridge divides the origin of the M. iliotibialis from the M. iliofemoralis. I cannot find reference to the processus supratrochantericus in Baumel and Witmer (1993). Hutchinson (2001a) reproduces the *Meleagris* pelvic diagram of Baumel and Witmer (1993), illustrating the processus supratrochantericus. However, in both Hutchinson (2001a) and Vanden

Berge and Zweers (1993) the processus supratrochantericus and its associated oblique ridge marks the division of the origin of M. iliofemoralis externus from the M. iliofibularis. Given this interpretation, the oblique ridge serves a role similar to that of the "vertical ridge" present in tyrannosauroid ilium—namely the division of the preacetabular concavity from the postacetabular concavity. Here I follow the conclusion of Hutchinson (2001a) and do not consider the "vertical ridge" and the oblique ridge below the supratrochanteric process homologous. Numerous tests of congruence reject this hypothesis as well as an incomplete satisfication of connectivity (e.g., no supratrochanteric process in Tyrannosauroidea).

Character 161: Brevis fossa

0: shelf-like

1: deeply concave with lateral overhang

Character 162: Antitrochanter posterior to acetabulum

0: absent or poorly developed

1: prominent

Character 163: 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

Redefined by MAE 05 following description of condition in *Unenlagia* and *Rahonavis* by Novas (2004) as confirmed by personal observation.

Character 164: Cuppedicus fossa

0: deep, ventrally concave

1: fossa shallow or flat, with little or no lateral overhang

2: absent

See (Hutchinson, 2001b) for explanation of related changes in pelvic musculature.

Character 165: Posterior edge of ischium

0: straight

1: with proximal median posterior process

Character 166: Ischium [MAE 05]

0: with rodlike shaft [i.e. part distal to ace tabular portion]

1: with wide, flat, and plate-like shaft

Character 167: Ischiadic shaft

0: straight

1: ventrodistally curved anteriorly

2: hooked posteriorly

Character 168: 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

Some dromaeosaurids have a distinct ridge (i.e. *Sinornithosaurus* and *Buitreraptor*) whereas other the ridge is subtle and forms a slight medial flexure of the obturator process (e.g. *Velociraptor* and *Deinonychus*). These are consider to be homologous. [MAE 05]

Character 169: 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 170: Obturator process

0: does not contact pubis

1: contacts pubis

Character 171: Obturator notch

0: present

1: notch or foramen absent

Character 172: Semicircular scar on posterior part of the proximal end of the ischium

0: absent

1: present

Character 173: Ischium

0: more than two-thirds

1: two-thirds or less of pubis length

Character 174: Distal ends of ischia ORDERED

0: form symphysis

1: approach one another but do not form symphysis

2: widely separated

Character 175: Ischial boot (expanded distal end)

0: present

1: absent

Character 176: Tubercle on anterior edge of ischium

0: absent

1: present

A small tuber occurring along the rostral edge of the ischium between the pubic peduncle and obturator process was described in *Velociraptor* (Norell and Makovicky, 1997) and is also present in *Deinonychus*. (Hutchinson, 2001b) termed this structure the obturator tuberosity.

Character 177: Pubis orientation

0: propubic

1: vertical

2: posteriorly oriented (opisthopubic)

3: appressed to ischium

The oviraptorid condition, in which the proximal end of the pubis is vertical and the distal end curves anteriorly, is considered to be state 1. This character was modified to include a fourth state for derived avialans and alvarezsaurids.

Character 178: Pubic boot projects

0: anteriorly and posteriorly

1: with little or no anterior process

2: no anteroposterior projections

Character 179: 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

MODIFIED. This character has been modified to include a third state to score the absence of a pubic apron in derived avialans.

Character 180: Pubic shaft

0: straight

1: distal end curves anteriorly, anterior surface of shaft concave

2: shaft curves posteriorly, anteriorly convex curvature

See also (Calvo et al., 2004).

Character 181: Pubic apron

0: about half of pubic shaft length

1: less than 1/3 of shaft length

Character 182: Contact between pubic apron [MAE 05]

0: contributions of both pubes meet extensively

1: contact disrupted by a slit

2: no contact

Character 183: Femoral head

0: without fovea capitalis (for attachment of capital ligament)

1: or circular fovea present in center of medial surface of head

Character 184: 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 185: Lesser trochanter of femur

0: alariform

1: cylindrical in cross section

Character 186: Lateral ridge

0: absent or represented only by faint rugosity

1: distinctly raised from shaft, mound-like

Hutchinson (2001a) clarified the terminological confusion surrounding this structure and considered it a derived homolog of the trochanteric shelf of more basal theropods and dinosauromorphs.

Character 187: Fourth trochanter on femur

0: present

1: absent

Character 188: Accessory trochanteric crest distal to lesser trochanter

0: absent

1: present

This character was identified as an autapomorphy of *Microvenator celer* (Makovicky and Sues, 1998), but it is more widespread.

Character 189: 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 190: Popliteal fossa between end of femur

0: open distally

1: closed off distally by contact between distal condyles

Character 191: Fibula

0: reaches proximal tarsals

1: short, tapering distally, and not in contact with proximal tarsals

Character 192: Medial surface of proximal end of fibula

0: concave along long axis

1: flat

Character 193: Deep oval fossa on medial surface of fibula near proximal end

0: absent

1: present

Character 194: 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 195: Tibia, cnemial crest(s)

0: lateral crest only

1: lateral and anterior crests developed (1).

MODIFIED definition following CEA 06 195.

Character 196: 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 197: Ascending process of astragalus

0: confluent with condylar portion

1: separated by transverse groove or fossa across base

Character 198: 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

MODIFIED following CEA 06 180.

Character 199: Distal tarsals

0: separate, not fused to metatarsals

1: fuses to metatarsal

MODIFIED. This character was modified to just refer to tarsal/metatarsal fusion.

Character 200: Metatarsals ORDERED

0: not co-ossified

1: co-ossification of metatarsals begins proximally

2: metatarsals fuse to each other proximally and distally

3: extreme distal fusion, distal vascular foramen closed

MODIFIED. This character was modified to expand its character states to encompass additional derived states in avialans. (Martin, 1983; Cracraft, 1986; CEA).

Character 201: Distal end of metatarsal II

0: smooth, not ginglymoid

1: with developed ginglymus

Character 202: Distal end of metatarsal III

0: smooth, not ginglymoid

1: with developed ginglymus

Character 203: MT III proximal shaft

0: prominently exposed between MT II and MT IV along entire metapodium

1: MT 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 MT III lost

Definition following Novas and Pol (2005; their char. 200).

Character 204: Ungual and penultimate phalanx of pedal digit II

0: similar to those of III

1: penultimate phalanx highly modified for extreme hyper-extension, ungual more strongly curved and significantly larger than that of digit III

Character 205: 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

MODIFIED. In the original formulation, State 3 scored for the absence of a metatarsal I. This state was dropped in lieu of a separation character that scores for the presence or absence of metatarsal I (C528). A new state was included to score for the location of metatarsal I on the medial side of metatarsal II near the distal end as is seen in many basal avialans (e.g., *Archaeopteryx lithographica* (Mayr et al., 2005),

Jeholornis prima IVPP V13353, *Yanornis martini* IVPP V12444, *Cathayornis yandica* (Zhou and Hou, 2002), *Concornis lacustris* Sanz et al., 1995), *Liaoningornis longidigitris* (Zhou and Hou, 2002)).

Character 206: Metatarsal I

0: attenuates proximally, without proximal articulating surface

1: proximal end of metatarsal I similar to that of metatarsals II-IV

Character 207: Shaft of MT IV

0: round or thicker dorsoventrally than wide in cross section

1: shaft of MT IV mediolaterally widened and flat in cross section

Character 208: Foot

0: symmetrical

1: asymmetrical with slender MTII and very robust MT IV, excluding flange

Senter et al. (2004) consider the foot of *Sinovenator* to be symmetric *contra* (Xu et al., 2002a), but examination of the holotype as well as several referred specimens confirms that the proximal part of MT II is mediolaterally compressed while the proximal section of Metatarsal IV is broadened, reflecting an incipient stage of asymmetry. Therefore we follow Xu et al. (2002a) in coding the foot of *Sinovenator* asymmetric (state 1). Although we acknowledge the difficulties in parsing states when characters display a more continuous range of expressions than originally defined, the asymmetric conditions is derived and the homology of even an incipient form of this state needs to be acknowledged and subjected to the test of congruence. If future discoveries reveal more taxa with the incipient condition a separate state may be warranted for it.

Character 209: Neural spines on posterior dorsal vertebrae in lateral view

0: rectangular or square

1: anteroposteriorly expanded distally, fan-shaped

Character 210: Shaft diameter of manual phalanx I-1

0: less than shaft diameter of radius.

1: greater than shaft diameter of radius.

Character 211: 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 212: Laterally inclined flange along dorsal edge of surangular for articulation with lateral process of lateral quadrate condyle

0: absent

1: present

Character 213: Distal articular ends of metacarpals I + II

0: ginglymoid

1: rounded, smooth

2: II ginglymoid and MC I shelf

This character has been modified to include the shelf like distal articular surface in derived avialans. This new character state follows CEA 06 146.1.

Character 214: Radius and ulna

0: well separated

1: with distinct adherence or syndesmosis distally

Character 215: Jaws

0: occlude for their full length

1: diverge rostrally due to kink and downward deflection in dentary buccal margin

Character 216: Quadrate head

0: covered by squamosal in lateral view

1: quadrate cotyle of squamosal open laterally exposing quadrate head

Character 217: 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 218: Vertical ridge on lesser trochanter

0: present

1: absent

Character 219: Supratemporal fenestra

0: bounded laterally and posteriorly by the squamosal

1: extends as a fossa on to the dorsal surface of the squamosal

Character 220: Dentary

0: fully toothed

1: only with teeth rostrally

2: edentulous

Character 221: Posterior edge of coracoid

0: not or only shallowly indented below glenoid

1: deeply notched just ventral to glenoid, glenoid lip everted

Character 222: Retroarticular process

0: points caudally

1: curves gently dorsocaudally

Character 223: Flange on supraglenoid buttress on scapula [Nicholls and Russell, 1985)

0: absent

1: present

Character 224: Depression (possibly pneumatic) on ventral surface of postorbital process of laterosphenoid (Makovicky et al., 2003)

0: absent

1: present

Character 225: 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

Modified from Makovicky et al., 2003. Basal tubera are absent in IGM 100/1128 and *Mahakala omnogovae* (IGM 100/1033).

Character 226: 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 227: Postacetabular end of ilium [MAE 05 227]

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

State 0 occurs in basal dromaeosaurids and basal troodontids whereas *Buitreraptor* and *Microraptor* have a lobate brevis shelf. The reduced brevis shelf of *Unenlagia* also appears to be slightly expanded.

Character 228: 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

MAE 05 228. Advanced troodontids and dromaeosaurids have a well developed, more symmetric heel, but more basal taxa within each clade including *Sinovenator*, *Microraptor*, *Buitreraptor, Rahonavis* and *Neuquenraptor* display state 0 with a weak, medially skewed heel (see also Senter et al., 2004).

Character 229: Large, longitudinal flange along caudal or lateral face of metatarsal IV

0: absent

1: present

Modified from Novas and Pol (2005). A low, rugose muscle scar is evident along the metaphysis of Metatarsal IV in many theropods and is probably a precursor to the flange considered here. Presence of the rugose scar does not constitute a distinct flange, however, here and is considered to fall under the conditions of state 0 here. Unlike Novas and Pol (2005) we consider the laterally directed flange of *Velociraptor* as homologous with the caudally directed flange in other paravians, because these structure occupy identical topological positions. Likewise, we consider this flange to be present in *Sinornithosaurus*.

Character 230: Proximodorsal process of ischium

0: small, tab-like or pointed process along caudal edge of ischium

1: process large proximodorsally hooked and separated from iliac peduncle of the ischium by a notch

MAE 05 203 State 1 occurs in *Unenlagia*, *Rahonavis*, *and Confuciusornis* and in some specimens of *Archaeopteryx* (Berlin, Solnhofen). Other basal paravian taxa that possess a proximodorsal process generally display state 0 including *Buitreraptor*, *Microraptor*, *Sinornithosaurus* and *Sinovenator*.

Character 231: Lateral face of pubic shaft

0: smooth

1: with prominent lateral tubercle about halfway down the shaft

(Senter et al., 2004). State (1) is observed exclusively in the Yixian Fm. dromaeosaurids *Microraptor* and *Sinornithosaurus*.

Character 232: Distally placed dorsal process along caudal edge of ischiadic shaft [Forster et al., 1998]

0: absent

1: present

Character 233: Obturator process

0: square (i.e. with distinct caudal edge or notch)

1: triangular with caudal end confluent with shaft

Character 234: Triangular obturator process with

0: short rostral projection and wide base along ischial shaft

1: short base, long process extending rostrally

State 1 occurs in a number of basal paravians including *Microraptor*, *Sinornithosaurus*, *Sinovenator*, *Rahonavis and Buitreraptor.* Due to incomplete preservations of the ischiadic margin in *Unenlagia*, the condition is difficult to determine, but we view this taxon as having state 1 based on firsthand observation of the holotype.

Character 235: 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

MODIFIED. This character was modified following CEA 06 198 to include an addition state found in derived avialans.

Character 236: Ulna/Femoral length ratio

0: significantly less than one

1: equal or greater than one

Character 237: Dorsal displacement of accessory (maxillary) fenestra

0: absent

1: present

In all dromaeosaurids with known cranial material, the maxillary fenestra is displaced dorsally within the antorbital fossa. In other theropods, this displacement is absent with the fenestra positioned more ventrally or central on the medial lamina of the maxilla. Modified from Senter et al., 2004: char. 5.

Character 238: Jugal process of maxilla, ventral to the external antorbital fenestra

0: dorsoventrally narrow

1: dorsoventrally wide

In some dromaeosaurids, such as *Tsaagan mangas* (IGM 100/1015) the jugal process of the maxilla is dorsoventrally wide. In other dromaeosaurids, such as *Velociraptor mongoliensis* (AMNH FR 6515) the jugal process of the maxilla is dorsoventrally narrow. Modified from Senter et al., 2004: char. 14.

Character 239: 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

All dromaeosaurids with known cranial material exhibit state 1. Witmer (1997: p43) discusses this morphology in detail.

Character 240: 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

Most theropods, including *Velociraptor mongoliensis*, have a prominent ascending ramus of the maxilla. In derived avialans this lamina becomes reduced or absent (Fig. 8). (modified from Gauthier, 1986 and Cracraft, 1986 by Chiappe, 1996: char. 6 by Clarke and Norell, 2002: char. 10).

Character 241: 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

In most theropods, the ventral ramus of the nasal process of the maxilla forms the anterior margin of the internal antorbital fenestra. A reduction and loss of this ramus is a trend within avialans. Modified from Clarke and Norell, 2002: char. 11.

Character 242: In lateral view, dorsal border of the internal antorbital fenestra formed by

0: lacrimal and maxilla

1: lacrimal and nasal

In all basal avialans, except *Archaeopteryx lithographica*, the nasal forms the dorsal border of the internal antorbital fenestra. In non−avialan theropods, including *Archaeopteryx lithographica*, the dorsal border is formed from the medial lamina of the ascending process of the maxilla.

Character 243: In lateral view, dorsal border of the antorbital fossa formed by

0: the lacrimal and maxilla

1: the lacrimal and nasal

2: maxilla, premaxilla, and lacrimal

In all basal avialans, including *Archaeopteryx lithographica*, the nasal forms the dorsal border of the antorbital fossa. This is because the ascending process of the maxilla in *Archaeopteryx lithographica* is recessed medially slightly.

Character 244: 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

The derived state is found in basal dromaeosaurids such as *Sinornithosaurus millenii*, basal troodontids like *Mei long*, and in the new taxon *Shanag ashile.* (Turner et al., 2007a).

Character 245: 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

A number of large theropods, dromaeosaurids, and some oviraptorosaurs exhibit state 1. This character is distinguished from character 42, which codes for the shape of the fossa on the frontal and postorbital. Modified from Currie 1995, by Currie and Varricchio, 2004: char. 14.

Character 246: Jugal

0: does not particulate in margin of antorbital fenestra

1: participates in antorbital fenestra

In *Allosaurus fragilis* and *Oviraptor philoceratops* the jugal does not participate in the margin of the antorbital fenestra.

Character 247: Anterior and posterior denticles of teeth

0: not significantly different in size

1: anterior denticles, when present, significantly smaller than posterior denticles

The anterior and posterior denticles in most theropods as well as *Dromaeosaurus albertensis* exhibit state 0. Most dromaeosaurids exhibit state 1. (see Ostrom, 1969a).

Character 248: Maxillary teeth

0: almost perpendicular to jaw margin

1: inclined strongly posteroventrally

Bambiraptor feinbergorum and *Atrociraptor marshalli* exhibit state 1. Modified from Currie and Varricchio, 2004: char. 40.

Character 249: Maxillary tooth height

0: highly variable with gaps evident for replacement

1: almost isodont with no replacement gaps

State 1 usually depicts no more than a 30% difference in height between adjacent teeth. (Currie and Varricchio, 2004: char. 41).

Character 250: Splenial forms notched anterior margin of internal mandibular fenestra

0: absent

1: present

State 1 is present in *Allosaurus fragilis* and *Tyrannosaurus rex*. (Currie and Varricchio, 2004: char. 35).

Character 251: 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

Modified from Currie, 1995; Currie and Varricchio, 2004: char. 42.

EXCLUDED Character 252: Articular, depression for depressor mandibular

0: oriented more dorsal than posterior

1: oriented mostly posteriorly

Currie et al., 2003: char. 1. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 253: Articular pneumatic

0: absent

1: present

Harris (1998). Currie et al., 2003: char. 2. This character has been excluded because it is redundant with C356.

EXCLUDED Character 254: Basioccipital, distance across basal tubera

0: less than the transverse width of condyle

1: greater than transverse width of occipital condyle

Holtz (1998). Currie et al., 2003: char. 4. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 255: Basisphenoid recess

0: oriented ventrally

1: oriented posteroventrally

Harris 1998. Currie et al., 2003: char. 7.

EXCLUDED Character 256: Ectopterygoid sinus

0: moderate

1: inflated

Holtz 2001: char. 69. Currie et al., 2003: char. 9. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 257: Exoccipital, ventral extension

0: notch separates basal tuber from more anteroventral extension of exoccipital-basisphenoid suture

1: no notch

Currie et al., 2003: char. 11. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 258: Exoccipital

0: no contact between left and right sides

1: contact above foramen magnum

Modified from Harris 1998, Holtz 2001: char. 66). Currie et al., 2003: char. 12. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 259: Frontal, suture for postorbital

0: little distinction between anterior and posterior parts of sutures

1: suture vertical anteriorly but is a distinct horizontal shelf posteriorly

Currie et al., 2003: char. 14. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 260: Frontal-parietal:

0: transverse dorsal sutures

1: frontals separated on midline

Currie et al., 2003: char. 15. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 261: Jugal, inflection on ventral margin below postorbital process

0: prominent but thin

1: prominent and thick

Currie et al., 2003: char. 18. After Carr, 1999. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 262: Jugal, pneumatopore

0: axis of pneumatopore inclined at an angle of 45 degrees to the ventral skull margin

1: axis of relatively small pneumatopore is horizontal

Currie et al., 2003: char. 19. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 263: Jugal, postorbital process in mature specimens

0: anteroposteriorly shorter at the base and convex laterally in all but the largest specimens

1: anteroposteriorly broad and shallowly concave laterally

Currie et al., 2003: char. 20. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 264: Jugal, postorbital ramus

0: tapering contact with postorbital

1: horizontal, interlocking notch for postorbital

Currie et al., 2003: char. 21.This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 265: Jugal, suborbital bar in mature specimens

0: tall, with orbital margin at same level as ventrolateral edge of lacrimal

1: low, with orbital margin lower than ventrolateral edge of lacrimal

Currie et al., 2003: char. 22. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 266: Lacrimal, angle between dorsal and preorbital rami in mature animals

0: approximately perpendicular

1: acute

Currie et al., 2003: char. 23. After Molnar (1991). This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 267: Lacrimal horn

0: prominent, well defined apex

1: elongate, robust edge

Currie et al., 2003: char. 24. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 268: Lacrimal, pneumatic openings in

0: multiple fossae

1: set in single fossa

Currie et al., 2003: char. 25. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 269: Lacrimal posterior end of apex (horn) in dorsal view

0: rounded

1: box-like

Currie et al., 2003: char. 26. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 270: Lacrimal, ventrolateral process of preorbital bar

0: forms posterior margin of antorbital fossa as it leads into the pneumatopore in the jugal

1: separated from the margin of the antorbital fossa ventrally by the jugal

Russell, 1970. Currie et al., 2003: char. 27. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 271: Maxilla, antorbital fossa ventral margin near back of tooth row in adults

0: coincides with lower margin of antorbital fenestra

1: lower than ventral margin of antorbital fenestra

Currie et al., 2003: char. 28. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 272: Maxilla, interdental plates

0: not fused

1: fused to each other

Currie et al., 2003: char. 29. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 273: Maxilla, palatal shelf suture for palatine

0: relatively shallow, tooth roots forming bulge on lateral side of dorsal surface

1: relatively deep, thereby obscuring positions of alveoli

Currie et al., 2003: char. 32. After Carr, 1999. This character has been excluded because it has not been thoroughly examined.

Character 274: Maxilla, promaxillary fenestra in adults

0: visible in lateral view

1: obscured in lateral view by ascending ramus of maxilla

Witmer 1997. Currie et al., 2003: char. 35.

EXCLUDED Character 275: Nasal, antorbital fossa

0: recesses absent from nasal

1: present

Currie et al., 2003: char. 37. After Holtz (1998). This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 276: Nasal, lateral finger-like lacrimal process oriented posteriorly clasps anterior end of lacrimal

0: present

1: absent in adults

Currie et al., 2003: char. 38.This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 277: Nasal, posterior region between lacrimals

0: expands laterally

1: lateral margins are parallel to midline or constricted posteriorly

After Russell 1970. Currie et al., 2003: char. 39. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 278: Nasal, posterior suture shape

0: medial projection extends as far or further posteriorly than lateral projections

1: lateral projections extend further posteriorly than medial projections

Holtz 2001: char. 48. Currie et al., 2003: char. 40. This character has been excluded because it has not been thoroughly examined.

Character 279: Nasal

0: dorsally flat for most of length

1: dorsally convex

Currie et al., 2003: char. 41.

Character 280: Nasal

0: unfused

1: fused

Holtz, 2001: char. 3. Currie et al., 2003: char. 42.

EXCLUDED Character 281: Palatine, shape

0: triradiate

1: inflated trapezoid

Holtz, 2001: char. 70. Currie et al., 2003: char. 43. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 282: Parietal, dorsal surface

0: flat with ridge bordering supratemporal fossa

1: parietals with sagittal crest

2: sagittal crest extends forward onto back of frontals

Currie et al., 2003: char. 44. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 283: Parietal, nuchal crest

0: as low or lower than the dorsal surface of the interorbital region

1: tall but transversely narrow

2: tall but broad

Currie et al., 2003: char. 45. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 284: Postorbital, dorsal surface in adults

0: rugose

1:

Holtz, 2001: char. 56. Currie et al., 2003: char. 46. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 285: Postorbital, suborbital process

0: not present or small

1: well developed in mature animals

After Holtz, 2001: char. 57. Currie et al., 2003: char. 47. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 286: Postorbital

0: smooth or slightly rugose posterodorsal to orbital rim

1: low, C-shaped crest

2: convex tablike prominence

Currie et al., 2003: char. 48. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 287: Prefrontal, anterior extension compared with anterior level of dorsal exposure of the frontal

0: extends beyond frontal

1: approximately same anterior extent or shorter

Currie et al., 2003: char. 49. After Carr, 1999. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 288: Premaxilla, nasal processes

0: slightly divergent at dorsal end

1: tightly appressed throughout entirely length, terminate as single tip

Holtz, 2001: char. 106. Currie et al., 2003: char. 51.This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 289: Premaxilla, tooth row arcade

0: more anteroposteriorly than mediolaterally oriented

1: more mediolaterally than anteroposteriorly oriented

Holtz, 2001: char. 2. Currie et al., 2003: char. 52. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 290: Quadrate, paraquadratic fenestra

0: large and between quadrate and quadratojugal

1: small and enclosed in dorsal ramus of quadrate

After Holtz, 1998. Currie et al., 2003: char. 53.This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 291: Quadrate, quadrate-quadratojugal suture in adults

0: unfused

1: fused

Holtz, 1998. Currie et al., 2003: char. 54. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 292: Quadratojugal, dorsal flaring towards contact with squamosal

0: virtually none

1: moderate

2: extensive

Currie et al., 2003: char. 56. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 293: Quadratojugal, subtemporal process

0: tapers anteriorly

1: squared off or double pronged anterior terminus

Currie et al., 2003: char. 57. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 294: Skull, contract amongst lacrimal, maxilla and nasal

0: multiple anterior prongs of the anterodorsal ramus of the lacrimal clasp processes of both maxilla and nasal

1: lacrimal process of the nasal dominant over maxillary contact with lacrimal

2: lacrimal process of nasal lost, maxilla-lacrimal contact dominates

Currie et al., 2003: char. 59. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 295: Skull, maxillary-nasal contact in mature specimens

0: smooth, longitudinal groove on each

1: interlocking transverse ridges

Currie et al., 2003: char. 60. This character has been excluded because it has not been thoroughly examined.

EXCLUDED 296: Skull, occipital region faces

0: posteriorly

1: posteroventrally

Holtz, 2001: char. 65. Currie et al., 2003: char. 63. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 297: Splenial foramen size

0: small

1: large

After Sereno et al., 1998. Currie et al., 2003: char. 66.

This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 298: Squamosal recess

0: absent

1: present

After Holtz, 1998. Currie et al., 2003: char. 68. This character has been excluded because it has not been thoroughly examined.

Character 299: Squamosal-quadratojugal flange constricting infratemporal fenestra

0: absent

1: present

Holtz, 2001: char 4. Currie et al., 2003: char. 69.

Character 300: Supraoccipital, pronounced, strongly demarcated median ridge

0: absent

1: present

After Holtz, 1998. Currie et al., 2003: char. 70.

EXCLUDED Character 301: Supraoccipital, pair of tab-like processes on supraoccipital wedge

0: absent

1: present

Holtz, 2001: char. 8. Currie et al., 2003: char. 71. This character has been excluded because it has not been thoroughly examined.

Character 302: Surangular, anteroventral extension divides external mandibular fenestra by contacting angular anteriorly

0: absent

1: present

Currie et al., 2003: char. 72.

Character 303: Surangular, posterior surangular foramen

0: small

1: large fenestra

Currie et al., 2003: char. 73. After Holtz, 2001: char. 12.

EXCLUDED Character 304: Surangular, shelf

0: horizontal

1: slightly pendant, overhangs dorsal margin of posterior surangular foramen

Holtz, 2001: char. 74. Currie et al., 2003: char. 74. This character has been excluded because it has not been thoroughly examined.

EXCLUDED Character 305: Teeth, premaxillary tooth size

0: subequal to lateral teeth

1: much smaller than lateral teeth

Holtz, 2001: char. 15. Currie et al., 2003: char. 75. This character has been excluded because it has not been toroughly examined.

EXCLUDED Character 306: Vomer, shape of anterior end

0: lanceolate (lateral margins parallel-sided)

1: diamond

This character has been excluded because it has not been thoroughly examined. Holtz, 2001: char. 110. Currie et al., 2003: char. 77.

Character 307: Vertical ridge on iliac blade above acetabulum

0: absent or poorly developed

1: well developed

Molnar et al., 1990. Rauhut, 2003 char. 172.

EXCLUDED Character 308: Anterior rim of ilium

0: convex or straight

1: distinctly concave dorsally

Rauhut (2003): char. 173. This character has been excluded because it is now redundant with the revised C156.

Character 309: Shape of premaxillary body

0: wider than high or approximately as wide as high

1: significantly higher than wide

Rauhut (2003): char 1.

Character 310: Dorsal surface of the nasals

0: smooth

1: rugose

Rauhut (2003): char. 18.

Character 311: Sublacrimal part of jugal

0: tapering

1: bluntly squared anteriorly

2: expanded

3: bifurcated

Rauhut (2003): char. 23. In its current form, adapted directly from Rauhut (2003) with one additional state (3), includes a state scoring for the presence of a blunted squared sublacrimal part of the jugal (state 1). Because this analysis is restricted to Coelurosauria no taxon is scored for this trait. Rauhut (2003) scored *Compsognathus longipes* as '0/1' because of ambiguity. Examination of MNHN CNJ 79 clarifies this scoring as state 0. State 1 was retained for future use do to bluntly squared anterior rami of jugals in basal theropods like *Coelophysis* and *Liliensternus liliensterni* (Rauhut, 2003: 53). State 3 (a bifurcated sublacrimal process of the jugal) is present in two basal troodontids from Mongolia.

Character 312: Pneumatization of the jugal

0: absent

1: jugal pneumatized by a foramen in the posterior rim of the jugal antorbital fossa

Sereno et al. (1996). Rauhut (2003): char. 26.

Character 313: Axial neural spine

0: sheet-like

1: anteroposteriorly reduced and rod-like

Molnar et al. (1990). Rauhut (2003): char. 93.

Character 314: Prezygapophyses in anterior postaxial cervicals

0: straight

1: anteroposteriorly convex, flexed ventrally anteriorly

Modified from Gauthier (1986).

Character 315: Pleurocoels in dorsal vertebrae ORDERED

0: absent

1: present in anterior dorsals

2: present in all dorsals

Holtz (1994) as modified by Harris (1998). Rauhut (2003): char. 106.

Character 316: Ratio femur/humerus ORDERED

0: more than 2.5

1: between 1.2 and 2.2

2: less than 1

Rauhut (2003): char. 139.

Character 317: Humerus in lateral view

0: sigmoidal

1: straight

Holtz (1994). Rauhut (2003): char. 143.

Character 318: Radius

0: more than half the length of humerus

1: less than half the length of humerus

Rauhut (2003): char. 145.

EXCLUDED Character 319: Deep groove on medial side of proximal end of fibula ORDERED

0: absent

1: present, but covering less than two-thirds of the width of the fibula

2: present and wide, covering more than two-thirds the width of the fibula

Modified from Sereno et al. (1996). Rauhut (2003): char. 210. THIS CHARACTER PARTIALLY OVERLAPS WITH CHAR. 192 OF THE CURRENT MATRIX.

Character 320: (CEA 06 1) 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 321: (CEA 06 7) Dentaries

0: joined proximally by ligaments

1: joined by bone

Character 322: (CEA 06 8) Mandibular symphysis, two strong grooves forming an anteriorly opening 'v' in ventral view

0: absent

1: present

Character 323: (CEA 06 9) 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 1/2 facial margin

2: maxillary process of the premaxilla extending more than 1/2 of facial margin

This character does not overlap with TWiG 20 and C20. TWiG 20 describes the length that the premaxillary process extends behind the external nares. CEA 06 09 describes how far the maxillary process extends along the facial or ventral margin of the side of the face. This character marks a shift in the morphology of the maxillary process of the premaxilla in early avialans. With the reduction of the maxillary process behind the nares and the elongation of the nares, the maxillary process in derived avialans begins to extend posteriorly along the ventral margin of the face in lateral view.

Character 324: (CEA 06 10) Nasal [frontal] process of premaxilla

0: short

1: long, closely approaching frontal

EXCLUDED Character 325: (CEA 06 11) Nasal process of maxilla, dorsal ramus

0: prominent, exposed medially and laterally

1: absent or reduced to slight medial, and no lateral, exposure

EXCLUDED Character 326: (CEA 06 12) Nasal process of maxilla, participation of ventral ramus in anterior margin of antorbital fenestra in lateral view ORDERED

0: present, extensive

1: small dorsal projection of the maxilla participates in the anterior margin of the antorbital fenestra, descending process of the nasals contacts premaxilla to exclude maxilla from narial margin

2: no dorsal projection of maxilla participates in anterior margin of the antorbital fenestra

Character 327: (CEA 06 13) Osseous external naris

0: considerably smaller than the antorbital fenestra

1: larger than the antorbital fenestra

Character 328: (CEA 06 14) Ectopterygoid

0: present

1: absent

Character 329: (CEA 06 15) 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 330: (CEA 06 16) Palatine and pterygoid

0: long, anteroposteriorly overlapping, contact

1: short, primarily dorsoventral, contact

Character 331: (CEA 06 17) Palatine contacts

0: maxillae only

1: premaxillae and maxillae

Character 332: (CEA 06 18) Vomer contacts premaxilla

0: present

1: absent

Character 333: (CEA 06 19) Coronoid ossification

0: present

1: absent

Character 334: (CEA 06 20) Projecting basisphenoid articulation with pterygoid

0: present

1: absent

EXCLUDED Character 335: (CEA 06 21) Basipterygoid processes

0: long

1: short (articulation with pterygoid subequal to, or longer than, amount projected from the basisphenoid rostrum)

Character 336: (CEA 06 22) 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 337: (CEA 06 23) Basisphenoid/pterygoid articulation, orientation of contact

0: anteroventral

1: mediolateral

2: entirely dorsoventral

Character 338: (CEA 06 24) 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 339: (CEA 06 25) 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 340: (CEA 06 26) Osseous interorbital septum (mesethmoid)

0: absent

1: present

Character 341: (CEA 06 27) Osseous interorbital septum (mesethmoid)

0: restricted to posterior or another just surpassing pre- maxillae/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 342: (CEA 06 28) Eustachian tubes

0: paired and lateral

1: paired, close to cranial midline

2: paired and adjacent on midline or single anterior opening

Character 343: (CEA 06 29) Eustachian tubes ossified

0: absent

1: present

Character 344: (CEA 06 30) 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 345: (CEA 06 31) 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 346: (CEA 06 32) Quadrate, orbital process ORDERED

0: pterygoid articulates with anterior-most tip

1: pterygoid articulation does not reach tip

2: pterygoid articulation with no extent up orbital process, restricted to quadrate corpus

Character 347: (CEA 06 33) 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 348: (CEA 06 34) Quadrate, well-developed tubercle on anterior surface of dorsal process

0: absent

1: present

Character 349: (CEA 06 35) Quadrate, quadratojugal articulation

0: overlapping

1: peg and socket articulation

Character 350: (CEA 06 36) Quadrate, dorsal process, articulation

0: with squamosal only

1: with squamosal and prootic

Character 351: (CEA 06 37) 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 352: (CEA 06 38) Quadrate, mandibular articulation

0: bicondylar articulation with mandible

1: tricondylar articulation, additional posterior condyle or broad surface

Character 353: (CEA 06 39) Quadrate, pneumaticity

0: absent

1: present

Character 354: (CEA 06 40) Quadrate, cluster of pneumatic foramina on posterior surface of the tip of dorsal process

0: absent

1: present

Character 355: (CEA 06 41) Quadrate, pneumatization, large, single pneumatic foramen

0: absent

1: posteromedial surface of corpus

Character 356: (CEA 06 42) Articular pneumaticity

0: absent

1: present

Character 357: (CEA 06 43) 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 358: (CEA 06 44) 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 359: (CEA 06 45) Mandibular symphysis, anteroposteriorly extensive, flat to convex, dorsal-facing surface developed

0: absent, concave

1: flat surface developed

Character 360: (CEA 06 46) Mandibular symphysis, symphyseal foramina

0: absent

1: present

Character 361: (CEA 06 47) Mandibular symphysis, symphyseal foramen/foramina

0: single

1: paired

Character 362: (CEA 06 48) Mandibular symphysis, symphyseal foramen/foramina

0: opening on posterior edge of symphysis

1: opening on dorsal surface of symphysis

Character 363: (CEA 06 49) Meckel's groove

0: not completely covered by splenial, deep and conspicuous medially

1: covered by splenial, not exposed medially

Character 364: (CEA 06 50) Anterior external mandibular fenestra

0: absent

1: present

Character 365: (CEA 06 51) Jugal/postorbital contact

0: present

1: absent

Character 366: (CEA 06 52) Frontal/parietal suture

0: open

1: fused

EXCLUDED Character 367: (CEA 06 53) Cervical vertebrae ORDERED

0: variably dorsoventrally compressed, amphicoelous ('biconcave': flat to concave articular surfaces)

1: anterior surface heterocoelous (i.e. mediolaterally concave, dorsoventrally convex), posterior surface flat

2: heterocoelous anterior (i.e. mediolaterally concave, dorsoventrally convex) and posterior (i.e. mediolaterally convex, dorsoventrally concave) surfaces

This character is partially redundant with C101 which scores for the type of vertebral articulation in the cervical and dorsal vertebrae. This character will be reword to just score for the degree of heterocoely present in heterocoelous cervicals.

***EXCLUDED* Character 367(revised): Heterocoelous cervical vertebrae**

0: anterior surface heterocoelous (i.e. mediolaterally concave, dorsoventrally convex), posterior surface flat

1: heterocoelous anterior (i.e. mediolaterally concave, dorsoventrally convex) and posterior (i.e. mediolaterally convex, dorsoventrally concave) surfaces

This is autapomorphic for *Ichthyornis dispar*.

Character 368: (CEA 06 54) Thoracic vertebrae (with ribs articulating with the sternum), one or more with prominent hypapophyses

0: absent

1: present

This character does not address the presence of hypapophyses on transitional vertebrae, or 'cervicothoracics', that do not have associated ribs that articulate with the sternum (e.g. Gauthier, 1986; Chiappe, 1996). In contrast, in Aves, well-developed hypapophyses are developed well into the thoracic series, on vertebrae with ribs articulating with the sternum.

Character 369: (CEA 06 55) Thoracic vertebrae, count ORDERED

0: 12 or more

1: 11

2: 10 or fewer

Character 370: (CEA 06 56) 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 371: (CEA 06 57) Thoracic vertebrae, parapophyses

0: rostral to transverse processes

1: directly ventral to transverse processes (close to midpoint of vertebrae)

Character 372: (CEA 06 58) Thoracic vertebrae, centra, length, and midpoint width

0: approximately equal in length and midpoint width

1: length markedly greater than midpoint width

Character 373: (CEA 06 59) Thoracic vertebrae, lateral surfaces of centra

0: flat to slightly depressed

1: deep, emarginated fossae

2: central ovoid foramina

Character 374: (CEA 06 60) Thoracic vertebrae with ossified connective tissue bridging transverse processes

0: absent

1: present

Character 375: (CEA 06 61) Notarium

0: absent

1: present

EXCLUDED Character 376: (CEA 06 62) Sacral vertebrae, number ankylosed ORDERED

0: less than 7

1: 7

2: 8

3: 9

4: 10

5: 11 or more

6: 15 or more (Chiappe, 1996)

This character has been excluded because it is now redundant with the revised C110.

Character 377: (CEA 06 63) Sacral vertebrae, series of short vertebrae, with dorsally directed parapophyses just anterior to the acetabulum ORDERED

0: absent

1: present, three such vertebrae

2: present, four such vertebrae

EXCLUDED Character 378: (CEA 06 64) Free caudal vertebrae, number

(0) more than 8

(1) 8 or less

This character has been excluded because it is encompassed by C121.

EXCLUDED Character 379: (CEA 06 65) Caudal vertebrae, chevrons, fused on at least one anterior caudal

0: present

1: absent

This character has been excluded because I am unaware of any theropods that fuse their chevrons to the caudal vertebrae; however Clarke (2004) only scored *Anas*, *Chauna*, and Crax as *state* 1. *Ichthyornis* was scored as 0 but Clarke noted no fused chevrons in the description (Clarke, 2004).

Character 380: (CEA 06 66) Anterior Free caudals prior to transition point; length of transverse processes

0: sub-equal to width of centrum

1: significantly shorter than centrum width

EXCLUDED Character 381: (CEA 06 67) Anterior free caudal vertebrae ORDERED

0: elongate pre/ postzygapophyses

1: pre- and postzygapophyses short and variably noncontacting

2: prezygapophyses clasping the posterior surface of neural arch of preceding vertebra, postzygapophyses negligible

This character has been excluded because it is now redundant with C120.

Character 382: (CEA 06 68) Distal caudals

0: unfused

1: fused

Character 383: (CEA 06 69) 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

EXCLUDED Character 384: (CEA 06 70) Ossified uncinate processes ORDERED

0: absent

1: present and unfused to ribs

2: fused to ribs

This character has been excluded because it is now redundant with C125.

Character 385: (CEA 06 71) Gastralia

0: present

1: absent

***EXCLUDED* Character 386: (CEA 06 72) Ossified sternal plates ORDERED**

0: unfused

1: fused, flat

2: fused, with slightly raised midline ridge

3: fused with projected carina

This character has been excluded because it is partially redundant with C128. A new revised character follows that deals just with the present and degree of development of the sternal keel or carina.

Character 386 (*revised*): Carina or midline ridge ORDERED

0: absent

1: slightly raised

2: distinctly projected

Character 387: (CEA 06 73) 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

Modified. This character has been modified to include an additional state scoring the morphology present in derived alvarezsaurids.

Character 388: (CEA 06 74) Sternum, dorsal surface, pneumatic foramen (or foramina)

0: absent

1: present

Character 389: (CEA 06 75) Sternum, pneumatic foramina in the depressions (loculi costalis; Baumel & Witmer, 1993) between rib articulations (processi articularis sternocostalis; Baumel & Witmer, 1993)

0: absent

1: present

Character 390: (CEA 06 76) Sternum, coracoidal sulci spacing on anterior edge

0: widely separated mediolaterally

1: adjacent

2: crossed on midline

Character 391: (CEA 06 77) Sternum, number of processes for articulation with the sternal ribs ORDERED

0: three

1: four

2: five

3: six

4: seven or more

Character 392: (CEA 06 78) Sternum: raised, paired intermuscular ridges (linea intermuscularis; Baumel & Witmer, 1993) parallel to sternal midline

0: absent

1: present

Character 393: (CEA 06 79) Sternum, posterior margin, distinct posteriorly projected medial and/or lateral processes ORDERED

0: absent (directly laterally projected zyphoid processes developed but not considered homologues as these are co- present 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 394: (CEA 06 80) Clavicles

0: fused

1: unfused

Currently state 1 is only scored in the dataset for *Hesperornis*.

Character 395: (CEA 06 81) Interclavicular angle (clavicles elongate)

0: greater than, or equal, to 90 degrees

1: less than 90 degrees

EXCLUDED Character 396: (CEA 06 82) Furcula, hypocledium ORDERED

0: absent

1: a tubercle

2: an elongate process

This character has been excluded because it is now redundant with the modified C132.

Character 397: (CEA 06 83) Furcula, laterally excavated

0: absent

1: present

This feature was noted by Chiappe and Calvo (1994) as an enantiornithine synapomorphy.

Character 398: (CEA 06 84) Furcula, dorsal (omal) tip

0: flat or blunt tip

1: with a pronounced posteriorly pointed tip

Character 399: (CEA 06 85) Furcula, ventral margin of apophysis

0: curved, angling

1: with a truncate or squared base

EXCLUDED Character 400: (CEA 06 86) Scapula and coracoid

0: fused

1: unfused

This character has been excluded because it is redundant with C135.

Character 401: (CEA 06 87) Scapula and coracoid 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 402: (CEA 06 88) Coracoid, procoracoid process

0: absent

1: present

EXCLUDED Character 403: (CEA 06 89) Coracoid

0: height approximately equal mediolateral dimension

1: height more than twice width, coracoid ‘strut-like’

This character has been excluded because it is subsumed by C136.

Character 404: (CEA 06 90) Coracoid, lateral margin

0: straight to slightly concave

1: convex

Character 405: (CEA 06 91) Coracoid, dorsal surface (= posterior surface of basal maniraptoran theropods)

0: strongly concave

1: flat to convex

Character 406: (CEA 06 92) Coracoid, pneumatized

0: absent

1: present

Character 407: (CEA 06 93) Coracoid, pneumatic foramen

0: proximal

1: distal

Character 408: (CEA 06 94) Coracoid, lateral process

0: absent

1: present

Character 409: (CEA 06 95) Coracoid, ventral surface, lateral intermuscular line or ridge

0: absent

1: present

Character 410: (CEA 06 96) Coracoid, glenoid facet

0: dorsal to, or at approximately same level as, acrocoracoid process/'biceps tubercle'

1: ventral to acrocoracoid process

Character 411: (CEA 06 97) Coracoid, acrocoracoid

0: straight

1: hooked medially

Character 412: (CEA 06 98) Coracoid, n. supracoracoideus passes through coracoid

0: present

1: absent

Character 413: (CEA 06 99) Coracoid, medial surface, area of the foramen n. supracoracoideus (when developed)

0: strongly depressed

1: flat to convex.

Character 414: (CEA 06 100) Angle between coracoid and scapula at glenoid

0: more than 90 degrees

1: 90 degrees or less

Character 415: (CEA 06 101) Scapula, posterior end

0: wider or approximately the same width as proximal dorsoventral shaft width

1: tapering distally

Character 416: (CEA 06 102) Scapula

0: straight

1: dorsoventrally curved

EXCLUDED Character 417: (CEA 06 103) Scapula, length

0: shorter than humerus

1: as long as or longer than the humerus

This character has been excluded because it is redundant with C139.

Character 418: (CEA 06 104) Scapula, acromion process

0: projected anteriorly to surpass the articular surface for coracoid (facies articularis coracoidea; Baumel & Witmer, 1993)

1: projected less anteriorly than the articular surface for coracoid

Character 419: (CEA 06 105) Scapula, acromion process

0: straight

1: laterally hooked tip

Character 420: (CEA 06 106) 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 421: (CEA 06 107) Humerus, proximal end, head in anterior or posterior view

0: strap-like, articular surface flat, no proximal midline convexity

1: head domed proximally

Character 422: (CEA 06 108) Humerus, proximal end, proximal projection

0: dorsal edge projected farthest

1: midline projected farthest

Character 423: (CEA 06 109) Humerus, ventral tubercle and capital incisure

0: absent

1: present

Character 424: (CEA 06 110) Humerus, capital incisure

0: an open groove

1: closed by tubercle associated with a muscle insertion just distal to humeral head

Character 425: (CEA 06 111) Humerus, anterior surface, well-developed fossa on midline making proximal articular surface appear v-shaped in proximal view

0: absent

1: present

Character 426: (CEA 06 112) 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 427: (CEA 06 113) Humerus, deltopectoral crest

0: projected dorsally (in line with the long axis of humeral head)

1: projected anteriorly

Character 428: (CEA 06 114) Humerus, deltopectoral crest ORDERED

0: less than shaft width

1: same width

2: dorsoventral width greater than shaft width

Character 429: (CEA 06 115) Humerus, deltopectoral crest, proximoposterior surface

0: flat to convex

1: concave

Character 430: (CEA 06 116) Humerus, deltopectoral crest

0: not perforate

1: with a large fenestra

Character 431: (CEA 06 117) Humerus, bicipital crest, pit-shaped scar/fossa for muscular attachment on anterodistal, distal or posterodistal surface of crest

0: absent

1: present

Character 432: (CEA 06 118) 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 433: (CEA 06 119) 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 434: (CEA 06 120) Humerus, proximal end, one or more pneumatic foramina

0: absent

1: present

Character 435: (CEA 06 121) Humerus, distal condyles

0: developed distally

1: developed on anterior surface of humerus

Character 436: (CEA 06 122) 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 437: (CEA 06 123) Humerus, distal condyles

0: subround, bulbous

1: weakly defined, 'strap-like'

Character 438: (CEA 06 124) 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 439: (CEA 06 125) Humerus, distal end, compressed anteroposteriorly and flared dorsoventrally

0: absent

1: present

Character 440: (CEA 06 126) Humerus, brachial fossa

0: absent

1: present, developed as a flat scar or as a scar-impressed fossa

Character 441: (CEA 06 127) 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 442: (CEA 06 128) 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 443: (CEA 06 129) Humerus, distal end, posterior surface, groove for passage of m. scapulotriceps

0: absent

1: present

Character 444: (CEA 06 130) Humerus, m. humerotricipitalis groove

0: absent

1: present as a ventral depression contiguous with the olecranon fossa

Character 445: (CEA 06 131) Ulna, cotylae

0: dorsoventrally adjacent

1: widely separated by a deep groove

Character 446: (CEA 06 132) Ulna, dorsal cotyla convex

0: absent

1: present

EXCLUDED Character 447: (CEA 06 133) Ulna, distal end, dorsal condyle, dorsal trochlear surface developed as a semilunate ridge

0: absent

1: present

This character has been excluded because it is redundant with C143.

Character 448: (CEA 06 134) 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 449: (CEA 06 135) Ulna, bicipital scar ORDERED

0: absent

1: developed as a slightly raised scar

2: developed as a conspicuous tubercle

Character 450: (CEA 06 136) Ulna, brachial scar

0: absent

1: present

Character 451: (CEA 06 137) Radius, ventroposterior surface

0: smooth

1: with muscle impression along most of surface

2: deep longitudinal groove

Character 452: (CEA 06 138) Ulnare

0: absent

1: present

Character 453: (CEA 06 139) Ulnare

0: 'heart-shaped', little differentiation into short dorsal and ventral rami

1: V-shaped, well- developed dorsal and ventral rami

Character 454: (CEA 06 140) Ulnare, ventral ramus (crus longus, Baumel & Witmer, 1993)

0: shorter than dorsal ramus (crus brevis)

1: same length as dorsal ramus

2: longer than dorsal ramus

Character 455: (CEA 06 141) Semilunate carpal and metacarpals ORDERED

0: no fusion

1: incomplete proximal fusion

2: complete proximal fusion

3: complete proximal and distal fusion

EXCLUDED Character 456: (CEA 06 142) Semilunate carpal, position relative to metacarpal I

0: over 1/2 or more of proximal surface

1: over less than 1/2 proximal surface

This character has been excluded because it is redundant with the revised version of C148.

Character 457: (CEA 06 143) 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 458: (CEA 06 144) 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 459: (CEA 06 145) 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

EXCLUDED Character 460: (CEA 06 146) Metacarpal I, distal articulation with phalanx I

0: ginglymoid

1: shelf

2: smooth

This character has been modified to score for the non-ginglymoid articulation present in Ornithomimosaurs. This character has been excluded because it is redundant with the revised version of C213.

Character 461: (CEA 06 147) Pisiform process

0: absent

1: present

Character 462: (CEA 06 148) Carpometacarpus, ventral surface, supratrochlear fossa deeply excavating proximal surface of pisiform process

0: absent

1: present

Character 463: (CEA 06 149) 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 464: (CEA 06 150) Carpometacarpus, distal end, metacarpals II and III, articular surfaces for digits

0: metacarpal II sub- equal or surpasses metacarpal III in distal extent

1: metacarpal III extends further

Character 465: (CEA 06 151) Intermetacarpal process or tubercle ORDERED

0: absent

1: present as scar

2: present as tubercle or flange

Character 466: (CEA 06 152) Manual digit II, phalanx 1

0: subcylindrical to subtriangular

1: strongly dorsoventrally compressed, flat caudal surface

Character 467: (CEA 06 153) Manual digit II, phalanges

0: length of phalanx II-1 less than or equal to that of II-2

1: longer

Character 468: (CEA 06 154; Clarke & Chiappe, 2001) Manual digit II, phalanx 2, internal index process on posterodistal edge

0: absent

1: present

Character 469: (CEA 06 155) Ilium, ischium, pubis, proximal contact in adult ORDERED

0: unfused

1: partial fusion (pubis not ankylosed)

2: completely fused

Character 470: (CEA 06 156) Ilium/ischium, distal co-ossification to completely enclose the ilioischiadic fenestra

0: absent

1: present

EXCLUDED Character 471: (CEA 06 157; CN 02 155) Ischium

0: forked (dorsal process present)

1: straight, no dorsal process

This character has been excluded because it is redundant with C165.

Character 472: (CEA 06 158; CN 02 156) Ischium, dorsal process

0: does not contact ilium

1: contacts ilium

EXCLUDED Character 473: (CEA 06 159; CN 02 157) Ischium and pubis ORDERED

0: not subparallel, pubis directed nearly directly ventrally

1: subparallel, pubis posteriorly directed

2: pubis appressed to ischium

This character has been excluded because it is redundant with the revised C177.

Character 474: (CEA 06 160; CN 02 158) Laterally projected process on ischiadic peduncle (antitrochanter)

0: directly posterior to acetabulum

1: posterodorsal to acetabulum

Character 475: (CEA 06 161; CN 02 159) Ilium, preacetabular pectineal process (Baumel & Witmer, 1993) ORDERED

0: absent

1: present as a small flange

2: present as a well-projected flange

Character 476: (CEA 06 162; CN 06 160) Preacetabular ilium

0: approach on midline, open, or cartilaginous connection

1: co-ossified, dorsal closure of 'iliosynsacral canals'

Character 477: (CEA 06 163; CN 02 161) Preacetabular ilium extends anterior to first sacral vertebrae

0: no free ribs overlapped

1: one or more ribs overlapped

Character 478: (CEA 06 164; CN 02 162) Postacetabular ilium

0: dorsoventrally orientated

1: mediolaterally orientated

Character 479: (CEA 06 165; CN 02 163) Postacetabular ilium, ventral surface, renal fossa developed

0: absent

1: present

Character 480: (CEA 06 166; CN 02 164) Ilium, m. cuppedicus fossa as broad, mediolaterally orientated surface directly anteroventral to acetabulum

0: present

1: surface absent, insertion variably marked by a small entirely lateral fossa anterior to acetabulum

EXCLUDED Character 481: (CEA 06 167; CN 02 165) Ischium, posterior demarcation of the obturator foramen

0: absent

1: present, developed as a small flange or raised scar contacting/fused with pubis and demarcating the obturator foramen distally

This character codes for the presence of an obturator process and therefore has a much larger distribution than just derived birds. The character is excluded because it is redundant with C169 and others that score for the presence and shape of the obturator process.

EXCLUDED Character 482: (CEA 06 168) Ischium, length relative to that of pubis

0: 1/3 or greater total pubis length extends posterior to end of ischium 1: less than 1/3 pubis extends further than end of ischium

This character has been excluded because it is redundant with C173.

Character 483: (CEA 06 169; CN 02 166) Pubis

0: suboval in cross section

1: compressed mediolaterally

Character 484: (CEA 06 170; CN 02 167) Pubes, distal contact

0: contacting, variably co- ossified into symphysis

1: noncontacting

EXCLUDED Character 485: (CEA 06 171) Distal end of pubis

0: expanded, flared

1: straight, subequal, in proportion with rest of pubis

This character has been excluded because it is redundant with C178.

EXCLUDED Character 486: (CEA 06 172) Femur, fossa for insertion of lig. capitis femoris

0: absent

1: present

This character has been excluded because it is redundant with C183.

Character 487: (CEA 06 173; Chiappe, 1991) Femur, posterior trochanter ORDERED

0: present, developed as a slightly projected tubercle or flange

1: hypertrophied, 'shelf-like' conformation (in combination with development of the trochanteric shelf; see Hutchinson, 2001a)

2: absent

EXCLUDED Character 488: (CEA 06 174) Femur, lesser and greater trochanters:

0: separated by a notch

1: developed as a single trochanteric crest

This character has been excluded because it is redundant with C184.

Character 489: (CEA 06 175) Femur, patellar groove

0: absent

1: present

Character 490: (CEA 06 176) Femur, ectocondylar tubercle and lateral condyle

0: separated by deep notch

1: form single trochlear surface

Character 491: (CEA 06 177) Femur, posterior projection of the lateral border of the distal end, continuous with lateral condyle

0: absent

1: present

This corresponds to the caudal intermuscular line that slants down to the medial

Character 492: (CEA 06 178) Laterally projected fibular trochlea ORDERED

0: absent

1: present, developed as small notch

2: a shelf-like projection

EXCLUDED Character 493: (CEA 06 179) Femur, popliteal fossa

0: a groove open distally and bounded medially and laterally by narrow condyles

1: closed distally by expansion of both condyles (primarily the medial)

This character has been excluded because it is redundant with C190.

EXCLUDED Character 494: (CEA 06 180) Calcaneum and astragalus ORDERED

0: unfused to each other or tibia in adult

1: fused to each other, unfused to tibia

2: complete fused to each other and tibia

This character has been excluded because it is redundant with the revised C198.

***EXCLUDED* Character 495: (CEA 06 181) Tibia, cnemial crest(s)**

0: lateral crest only

1: lateral and anterior crests developed

This character has been excluded because it is redundant with C195.

Character 496: (CEA 06 182) Tibia/tarsal formed condyles

0: medial condyle projecting further anteriorly than lateral

1: equal in anterior projection

Character 497: (CEA 06 183) Tibia/tarsal formed condyles, extensor canal ORDERED

0: absent

1: an emarginated groove

2: groove bridged by an ossified supratendoneal bridge

Character 498: (CEA 06 184) Tibia/tarsal formed condyles, tuberositas retinaculi extensoris (Baumel & 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 499: (CEA 06 185) Tibia/tarsal formed condyles, mediolateral widths ORDERED

0: medial condyle wider

1: approximately equal

2: lateral condyle wider

Character 500: (CEA 06 186) Tibia/tarsal formed condyles

0: gradual sloping medial constriction of condyles

1: no medial tapering of either condyle

Character 501: (CEA 06 187) 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 502: (CEA 06 188) Tibia, extension of articular surface for distal tarsals/tarsometatarsus ORDERED

0: no posterior extension of trochlear surface, or restricted to distal-most edge of posterior surface

1: well-developed posterior extension, sulcus cartilaginis tibialis of Aves (Baumel & Witmer, 1993), distinct surface extending up the posterior surface of the tibiotarsus

2: with well-developed, posteriorly projecting, medial and lateral crests

Character 503: (CEA 06 189) Tibia, distal-most mediolateral width

0: wider than mid-point 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

EXCLUDED Character 504: (CEA 06 190) Fibula

0: reaches tarsal joint articulating into distinct socket formed between the proximal tarsals and the tibia

1: reduced in length, does not reach tarsal joint

This character has been excluded because it is redundant with C191

EXCLUDED Character 505: (CEA 06 191) Distal tarsals and metatarsals, fusion ORDERED

0: distal tarsals fuse to metatarsals,

1: distal tarsals fuse to metatarsals and proximal metatarsals co-ossify,

2: distal tarsals fuse to metatarsals, and metatarsals fuse to each other proximally and distally,

3: extreme distal fusion, distal vascular foramen closed

This character has been excluded because it is redundant with C199 and the revised version of C200. (Martin, 1983; Cracraft, 1986)

Character 506: (CEA 06 192) Metatarsal V

0: present

1: absent

Character 507: (CEA 06 193) Metatarsal III

0: proximally in plane with II and IV

1: proximally displaced plantarly, relative to metatarsals II and IV

Character 508: (CEA 06 194) Tarsometatarsus, intercotylar eminence

0: absent

1: well developed, globose

Character 509: (CEA 06 195) 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 510: (CEA 06 196) Tarsometatarsus, proximal vascular foramen (foramina) ORDERED

0: absent

1: one, between metatarsals III and IV

2: two

Character 511: (CEA 06 197) 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

EXCLUDED Character 512: (CEA 06 198) Metatarsal II tubercle 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

This tubercle is associated with the insertion of the tendon of the m. tibialis cranialis in Aves.

Character 513: (CEA 06 199) 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

EXCLUDED Character 514: (CEA 06 200) Metatarsal II, articular surface for first phalanx

0: ginglymoid,

1: rounded.

This character has been excluded because it is redundant with C201.

Character 515: Metatarsals, relative mediolateral width

0: metatarsal IV approximately the same width as metatarsals II

1: metatarsal IV narrower than MII and MIII

2: metatarsal IV greater in width than either metatarsal II or III

MODIFIED from CEA 06 201

Character 516: 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.

MODIFIED. A fourth character state has been added to CEA 06 202

Character 517: (CEA 06 203) Distal vascular foramen

0: simple, with one exit

1: forked, two exits (plantar and distal) between metatarsals III and IV.

Character 518: (CEA 06 204) 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 519: (CEA 06 205) 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 520: [NEW] Middle to posterior caudal vertebrae

0: 2x or less the length of dorsal vertebrae

1: 3x-4x length of dorsal vertebrae

Character 521: [NEW] Coracoid fenestra

0: absent

1: present

Character 522: [NEW] Metatarsal V, elongated and bowed

0: absent

1: present

Character 523: [NEW] Posterior extension of caudal chevrons

0: not significantly elongated

1: very elongated

Character 524: [NEW] Radius width

0: roughly half or greater than width of ulna

1: less than half width of ulna

Character 525: [NEW] Combined length of MC I plus phalanx I-1

0: greater than length of MC II

1: equal to or less than length of MC II

Character 526: [NEW] Metacarpal III

0: straight

1: bowed

Character 527: [NEW] Metatarsal I

0: distal end of trochlea proximally placed relative to other metatarsals

1: inline distally with others

This is an enantiornithes synapomorphy.

Character 528: [NEW] Metatarsal I

0: present

1: absent

Character 529: [NEW] Development of the preotic pendent ORDERED

0: absent

1: present but small

2: present and robust

Character 530: [NEW] Shape of the metotic strut

0: short and robust

1: long and narrow

Character 531: [NEW] Prootic recess ORDERED

0: absent

1: present and shallow

2: present and deep

Character 532: [NEW] 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

Presence of the ATR creates a distinct crest or angle marking the posterior and dorsal border of the ATR. This crest I will refer to as the *anterior tympanic crista*.

Character 533: [NEW] Location of ATR and the anterior tympanic crista

0: below the CN VII exit just proximal to the otic recess

1: anteriorly with little or no development posterior to the basipterygoid processes

Character 534: [NEW] ATR confluent with the subotic recess

0: absent

1: present, forming the Lateral Depression

Character 535: [NEW] V-shaped opening between basal tubera remnants

0: absent

1: present

This is probably a remnant of the craniopharyngeal foramen/duct.

Character 536: [NEW] Small tubera (not basal tubera) medial to basal tubera (or basal tubera remnants) and ventral to occipital condyle

0: absent

1: present

Character 537: [NEW] 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 538: [NEW] Sternal plates

0: unossified

1: ossified

Character 539: [NEW] Ulna, size of proximal cotylae

0: unequal, lateral (dorsal in birds) smaller

1: equal

Character 540: [NEW] Middle ear resides within the Lateral Depression

0: absent

1: present

Character 541: [NEW] Filamentous integumentary structures (Stage 1 feathers)

0: absent

1: present

Character 542: [NEW] Vaned feathers (Stage 4 feathers)

0: absent

1: present

Character 543: [NEW] Quadratojugal size

0: large

1: greatly reduced

Character 544: [NEW, based on Currie, 1985) Notch for postorbital contact on postorbital process of frontal

0: absent, process smooth or facet small

1: large notch present

Character 545: [NEW] Position of fronto-parietal 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 546: [NEW] Orientation of articular surfaces between cervical vertebrae

0: surfaces vertical to subvertical

1: strongly slanted anteroventrally

Character 547: [NEW] Accessory depression in supratemporal fossa

0: absent

1: present

Character 548: [NEW] Relative ventral extension of pubic versus ischiadic peduncles

0: equal

1: pubic peduncle extends farther ventrally

Character 549: [NEW, partially reworded from C6] 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 550: [Nesbitt et al., 2009] Cross-section of the furcula

0: nearly circular

1: anteroposteriorly compressed near the symphysis

The furculae from more basal members of the Theropoda (e.g., *Coelophysis*) are rounded in cross-section. Oviraptorid furculae are more oval in cross-section but still differ from the anteroposteriorly compressed furculae in most paravians whereas the furcula of *Suchomimus* is D-shaped in cross-section (Lipkin in press).

Character 550: [Nesbitt et al., 2009] General shape of the furcula

0: V-shaped

1: U-shaped

The unfused articulated clavicles in *Massospondylus* are v-shaped. This shape is found in most of the early theropods with furculae including "*Syntarsus" kayentakatakae*, *Suchomimus,* and *Allosaurus*. The furculae of all coelurosaurs except *Velociraptor* and those of *Coelophysis rhodesiensis* and *Coelophysis bauri* are u-shaped.

Character 552: [Nesbitt et al., 2009] Epicledial processes

0: unexpanded

1: expanded

The furculae of most theropods have unexpanded epicledial processes. Expanded epicledial processes are present in tyrannosaurids as identified by Makovicky and Currie (1998). Some variation in

the size of the epicledial processes is present in *Allosaurus* as noted by Chure and Madsen (1996). The slight expansion of the epicledial processes in *Allosaurus* is smaller than the expansion of the epicledial processes of tyrannosaurids.

Character 553: [Nesbitt et al., 2009] Lateral expansion of the rami between the hypocledium and the epicledial process

0: absent

1: present

The ramus of the furcula normally is the same width as the epicledial processes and the hypocledium region. Oviraptorids have an expanded ramus.

Character 554: [Nesbitt et al., 2009] Hypocledium

0: rounded

1: keeled

The hypocledium of oviraptorids is either smooth or keeled. A keeled hypocledium is present in *Oviraptor* and "big momma" (IGM 100/979).

Character 555: [Nesbitt et al., 2009] Furcula

0: asymmetrical

1: nearly symmetrical

The furculae of most non paravian theropods are highly asymmetrical (e.g., *Allosaurus, Citipati*). The furculae of paravians, with the exception of *Buitreraptor,* are nearly symmetrical. It is not clear if the asymmetry of the furcula of *Buitreraptor* was the result of taphonomy or represents real morphology.

Character 556: [Nesbitt et al., 2009] Furcula rami

0: thin

1: thick

This refers to the thickness of the rami and hypocledium region. With the exception of *Mei, Archaeopteryx*, *Confuciusornis*, and *Changchengornis* all non-avian theropods have relatively thin furculae. The furculae of *Mei*, *Archaeopteryx*, *Confuciusornis*, and *Changchengornis* all have thick, robust furculae.

APPENDIX 4: DATA MATRIX

Allosaurus fragilis

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Citipati osmolskae

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111?1?????????10111011001011111001??201??00210011 1?01112001101001 00?1100000010
00211001??01012010??10101111?2101000000000?000000000000000000001102000000?0?0
01000?00000201 1???0??????????????????????????????[01]?????????????????0000???0
00100001210020100011000001?1102?1??0000??000001000101 0??0000?020011000001[01]0
0?100?00100001201002 0???????0????0111000?0?0010000?000000000000?000100?0???0?
00???00000001?0???0000??0???2?000000000000000040000000102?000?00000000001000
00110??00[01]10?01101100

Rinchenia mongoliensis

?01?0????0?????????0111?1???1?11?00010??00???000?0??????00??1?12112??01000??
111?1?????????????????1?????????????0?????210?????????2??1???00?0???10??00010
00?1?????1?????????????????1?????????0????0??0?0????????0??00??001??2?00????????
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1100????????2??010010??????????10?0?10??0???0????????????0?????????????????????
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Oviraptor philoceratops

?01?0??????01?1????0??1??111?1011???0???1?0?11????0?1?0???0?11?121120?01?00?0
1?1?1?????????????????????????????0??????????????12??1?????00???1?0??00?0
0??1??0?????????????????????????????0????0????0??0?????00?00000???2?00?0??????
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??00????00????0?0000??????????10?0?00??0??00?00?1?1????00????00?100??????????0
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Conchoraptor gracilis

?0110??????????1???00111?1???1?11?000??2100011O?000?????1?0????121120?010?0?0
111?1??????????0101011001O??1?012?110??10????01?1?????2001100001O????????0010
00210001010100201O??101001?1?11010000??0001000001O?000??000?001102?0?0000?0?0
0100000000020O1??????????????????????????????0??????????????????0??????0?
1000012???????0000000000?0?????????10???0100100????????000???0?010???????????
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Incisivosaurus gauthieri

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1?000210??00?0??
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1000???????000000000001?010001??0000???0000101?1100??0000?????????????????
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Microvenator celer

??21?20?0??????
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002???0000?????????????0110??0101100?0000010???????0??0???00??11?20?0??00???0?1??0??0?????0?21000000???0?0001???????0?????????????????1200000?000?01??????00?0??010?00?000000000000010000?????00???????????0?????0??000??000?2000000000000000?????????????????0??0?????????????1????????0????????

Chirostenotes pergracilis

?????1??01?01101??0???1?110?0????????????????????????01010??????21120?00000?01???1?????????????????1101?11????1?12???0?????????????????101?1???????????00?1000021?00101012120101110?011???01??100???00?100000200000??000?0?1??20?0?000?0?00100???000????0??????[12]?????10??00??????10101????00????????????01?10???0?????0011??000100????????????????120?000?00000???000001?000??00010000???00?0?????????????000000???0???0000?????001010?00???0????????1???????

Caudipteryx zoui

00110?????????????????0?111??10?0001?10???21000???0?00?????????????21120?0??????????0?1??0?????00????0??00????1???0???01?????20?????0???0??0???01?0???100000?000?1??????0101201???1????101?11?????0????01000??1?00?0?000000?1102000??00?0?0010000000000?00????0?????????????????????????????????0?????????????????0??0????000000?1[01]100?000000000?????????????0??????0000????1000???000?0?00?0000001?00?10?????????????1200??0?0?000?10?1?00???????0?0???00?00????????0????1??0?0000???0000000?1?000000001000??0?0?0000?00????00[04]000000????0??2000000??0???????01101100??01?110???0

Dromaeosaurus albertensis

?0??001000000000010??0???0?01??01110????1111????10001?1001100??000000100111110
000?0000101001???
???1???11?1?0????00??????00?0?00??1???
??????1?00??0110001 0?????????????????????0?????0?????????????????????0?????
?????????????0???0?0000?0000000??0000??000000000000??00?????????????????????
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0???00?0?????????

Deinonychus antirrhopus

?0110????1????????1??0000?011100011100011111110 0?1????0000111010000?010011 1?1
000?0100101000?11000110 0?1111011????00110111121??????1?110111001001110000001 0
022111010101022 0?01111201201?111100000000010001101001000000000110000 0?00010?0
010001010000011110 11?????????????????????0????00?????????????????0???????0?
0001012100?000000000?0??????000????0???????????00000??0000?00000000??01[01]00?
?0?????????????1200000?000?0000111000?0?0010000?000000000000010 01?0???000000
0??01000001?1000?00000000?000000000000000000400000000000?000000000 0????????0
?1????00111????????

Velociraptor mongoliensis

?011001001000012011200001011100011100012111?10?0100010000111010000000100111 11
000101001010000110001100111110111110001101111211100101111111100100111000000 10
022111011101022010111121120111 11?000000000111011010010000000001100000000011?0
010101010000011100 11?????????????????????0????00?????????????????00?00???0?
0001011100?000000000000?00000000?0000??00000000?0000??0000??00000000001[01]00?
100??000?000100002000 00?000?0000111000?0?001000???000000000000100100???000000

0??01000001?10000000000000000000010000000000000000010000?0100000000010[12]1100
00110110001110000?10

Atrociraptor marshalli

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??0????0?????????
???????11?00??0??111??
??1?????????????0????????????????????????????????????0????0????????????????????
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Utahraptor ostrommaysorum

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????0????0101??1????0?1100?1??1????????0??011????????????101?1?????????????0?
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??0????10????0???0???00000?????????
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????????00?????????0??????0?0000???00000000???0000?0?????0?00????????????????
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Adasaurus mongoliensis

?0110?????0????2?????????????????0?????0?1??11?1?0?10001??001??0?????0????0?1???
0????????????01100?11?0111?10?111[01]100??011?1?1??????1?111111?????????????
?10221110101 01?2201?1?1121100 1?11100000?000?1101001001 0??00??00110?0?0?0001?
?00100??1??????11???00??0???

0??????1?????????????0???????????00??00???000?0???????????00?0?0010000000[01]0

0?????????????????020?0?0???00??001?10?????????????????????????????????????

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00??0??0001?1????????

Achillobator giganticus

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????0000101??????0?01100?11110???????0??011?11??????????101?????????????00??1

0220??1101000210 1?011010?001?21110?0????00?000?101????0????????1???0????001??0

0100011100??0??100??0?

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Tsaagan mangas

?0110010010000120112000010101000 1?10001211111000100011000010 0??000000100?1111

000101001010000 1100??1??????0?????????????????1????????11?111?????????????

??00??00??00?0000??????

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Saurornitholestes langstoni

??111?????????????11????0????????????

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1221?1?1?1?1?0??????????????????11??0????00??001101??00???00?0?1??00?000001?0?0
01000????????1110011???0?
?????1210??????????0?????????????????????00000??????????0?????????????????????
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Bambiraptor feinbergorum

?0110??001000012010[02]00?01011100?11000121111?10001?0?1?00011?0?0?000?0100?11
11000?010010100??1110?1100?1??100?0?1100[01]1011??2????0101011011110?001?1?000
00111?211?0101?102201?111021100???111000000000100011101?000000000001100000000011
11?0010?010100??11?110?????????????????????????0????00?????????????????0??00?
??0?000?012100?0?000??00?0??00?0000??0000??000000001?000??0000?00000100??????
0???0?0?0?0?00?000?20?000000000?001??000?0?0?1000??000000000?0001?0??????0?00
0?0??0000000???000?000??00??0?0000???00000000??000000???00?010?10000000011100
00110??00011101100?10

Sinornithosaurus millenii

0011??????0??????????00???1110????10001111100?1???0?01??0????????00?00100??1??
??010100??100????????1??1???????0???00?1??1???????01?1?1101111?0?????0?0000?0
0?201?01?111023?1?111021?2?1???1????????110001?1100?0?00010001??0000???01101
11100100000011110?0?????????????????????0?????0?????????????????????0?????????
?00????100?00?00000??????0???000????0????00000??1000??00?0?0?0?????000???0???
0???????00??0?1[12]00000???0?0000000?00?0??010?0??00?????????????0?????????0000
0??0000?000010??0?0?00000????????0?000??0?0??000?00??00???0011?11000????????0
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Microraptor zhaoianus

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??0?01000000?????001?1??01?1100?01???0110?1212111?01?10111111010??1101000011

012111??0111023?1?11102112O1?11111??00?000111011111O?100??000?11?000????10101

11100?0?0???1?110?????????????????????????0?????0?????????????????0???????0?

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100?0000?00100000200?0???0?000?00?0??10?0???10100?000??1?0?000??????????0000??

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Rahonavis ostromi

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1111?1011111O?3?1012101?121??2111000100O?01110110?0100????0??1?????0??100010

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Pyroraptor olympius

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Buitreraptor gonzalezorum

?0110????????????????00001011?00??????????100?10??0011?0?????????00??001??????
????0210??100?0010111100111?110???100011012[012]121???????0110111010?1?10??0?
?????11?101??11[02]23??01?1?1?120???11?0??0??1?011?0?1110000?????0??1?????????1
1010001100000000???0??????????????00??0000???????0????00?10100???2???????00???0
0??0??000?10100??00?000??????????????0???????0?000101???0?????00?000000000000[0
1]00????????????010000011000?0?0?00??0?100000?0?001100??00000100000001??100?????
????????????0000?????00?0?????0??00?0?0????????00?0?00??0000?0000?00?????????
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Neuquenraptor + Unenlagia

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1111?1011111022010111?111202011?10000??0?010??111100000????0??11????0??110110
?110???00
??????210???0?00000?00????????
??????????????11??????????????01?00?0?0?0011000?00000?????????????0???????????
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Shanag ashile

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Graciliraptor lujiatunensis

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??00?000??10???????????
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Mahakala omnogovae

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????02????1???00??0?11?011?111??1?10001101211O?????????????????00??11100000?10
0?211101?2?????????????????????0111100????0?01100110 1?00000??00??11?0?????0000??
???00????????0??0?
?????1[01]1?0?????????0?????????????????????0??1?000??????????0?000010000000[01]?
0????????????????????????????????????00???[01]0???0?0000???0?????????????????100?????
0???0???000000????0??001?????00????001?00000000???000000000?000??00?000????1
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Mononykus olecranus

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?????2????0????????1?1?1110110 1?????10?2???????1???1000?000200030110?112201100

??1????1??000?0?1?????3??0???2101001110112111000300000012??00???1??0?0??00?0?0
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220???00??????12?0??0?0?0?0?0010?0110??0002000?00[01]?0000?000??00000???3000?0
0???????0???[12]00????1?????021000101000000000?0??0000??000?00?0??0??000??????
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Shuvuuia deserti

?01101000000000?112011000?0?0?0?111?11002100001010100100101???1?100001010000021
00?10211??000??011111101110l?0??1?2010120121101001?000?00020003011??112201100
0?1??011?2000?0?10021032?0???2101001110112l1[01]000300000011000001100000010000
?00??000000000001?0100????????????????????????????00?????????????????0000????
0?0000?10010000000000??101?000??1??00110?01?1000??0[12]0????010?0?00100010010?0
0??0220?0??0??????1200?10?000?0100010011l??0001000?00[01]?0000?000??0???????30
00?00??000??001?20?0?00100002?2100010[01]000000000??0?000000000?00000000?00000
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Patagonykus puertai

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?1????1????1??0?????10????21101??1100?000100001110??0????0?1??0?0?1???00?????
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Alvarezsaurus calvoi

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0011??0??2?????????????????????1?00???0??0??10000000???0????????1???0????00????

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Proceratosaurus bradleyi

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Ornitholestes hermanni

?0100???0?0?00?1???0?010?01110001?100001?0??10000000?01011????0000001000?0?0

00010?00101001????011?0101110000??000?0010??1?????????????????01?00??????????0

0001??1?0?0[01]00100000001??0?1???????0????????00?00????00000?0010?00?0?0000?0

?0000?0000000??01?0??0?????????????????????0????00?????????????????0000??0?

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0?????????????????????????????????????0?0?0010000?000000000000??00??0?????10

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0??0???0001?0????????

Coelurus fragilis

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Archaeopteryx lithographica

101?0000??000??11201001O??1110?01100001210O?10?0000?0??100111?0?0000010000002?
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11211101O?1100301012102l?212?111100000?000100000030?000000001100000??00?000
1100100000010O1?0100??????????????????????0????00?????????????????0?????????
00000?0200?00?000000000??000110??00?0??000?00??000???00?00?0000000[01]0000000?
00????????0000000?00000?000000000000000?0011000?000??000?00001000000??000000
0?000000000000?0?000000?000000000?00?0?[01]1010000000?100???0000010000101000
000101110l?0101100?10

Avimimus portentosus

?01?0???10011?00??0??1?1????????1???1????00?11??0?00100110??????2?1???00?0??0
111?????????????011010110101?1?00??100?????????????????????????0100????????????0
0?211?01??0101201010?010?0?1000100?0???000111100?0???00??0?0?01?02?000000?0?0

01000????????0???00??????0?
1???0?010021?????????????????????????0??0???00?00???????????02001000??01??????
??????????????????????????????0??????0?0?0010000?000000000?????????????2???????
??????[02]01?0000?000100000200?01?10000000000100000?0?000?01??0??????0????????
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Confuciusornis sanctus

10110?????????????????1?000?00??0001???0??2??0??0??010???01???????0000010000?10?0
001?1?????????0???????????1011?0?2???0?2????3??111?11010??1311100?11111000000
1121?1?1??11000?1?111022?21?12??10??11??12021101003O?000000000110200O??00?010
1??11?000011001?????????????????????????????????0?????????????????????????????
0000?12200?1[01]0010010???????????10??00??011200??01[12]011111000000011001010000
10[01]010001200001?000?01000?0??0??000000000?000211??00100000000101002101011 1[
01]?100?000000100100000000000001110101120001000111100001110100?00?0000[01]000??
?1000001101110?00??1100?10

Struthiomimus altus

?01010?110??0??10102100010111O1?1100000000000000001?0??0001?01??0001000001020
001?1?????????001?10110000101000101000000001001001????01120002000000?101001
0000001100001010010000000001000001100010001000020??000011111110121110000?0?0
0100000000000O1?????????????????????????????????00?????????????????????????00
0000??2110?????000?????????????0?0?1????000?????0?00???00??0000?0000001[01]00?
00?????????????020???0?0?000?00011101?0?0010000??000000000000??00???0??000002
0??000000000000000000?000002000?000000000000000000000?0?100?020000000?1002??0??0
0????0?00?00???????

Gallimimus bullatus

?01010?1101101010102100010 11?01?1100000000000000001000000 01?0100000000001020
001?1?????????001110110000101000 1?1000000001001 00?????01120002000 00?0?101001
0000001100001010010000001001000001100010001000020??0000011111101211100 00?0?0
0100000000000 01?????????????????????????????????00?????????????????1000???00
0000002110200?000000[01]00100100000?0000???000000010200??1000?000010000001[01]0
0??0?????????????1200?00?000000001110 01?0?0010000?0000000?0?000?00???1??0?00
020??00000201?00?0?00010000?2000000000000000040100 0??0100?01000000??1002??00
00??0??00000?0???????

Garudimimus brevipes

?010?????01101?????2?00010101000??000?00?00?0?000?????0001??1?0??0??0??0?02?
0?1?1?????????????????????????1???1??0??
?0?0???1???0?0????????0??0?1???????0???????000000000?0??01??1?1??2?1?0?00?0?0
??000100000000?????????????????????????????????0?????????????????00?0????0?
0000010???[12]00?000000?001?0?00000?0000??000001011000 0??0000?0000100000?1?0??
?0??
????????00??00000000??0000200000000000100000400000 0?0103?010?0????0000???000?
??0??001000????????

Pelecanimimus polydon

?01???????1????????2?00????100?????????0??0??????????????????????00?0000?????
??000211??0001?????????????????????????????????????0?00????2?????00??00?1010??
??001110????0?????0?????
0????000?0??0?1?0??
00?00?0?10????0?000?????????????0?0?????????????????????0????????0????????????
??????????????1?00????0?0?????????????????????????????????????1??0?0000??
?00000???0??000????????????0?
????0??0?????????

Harpymimus okladnikovi

?0??????????????????2?0??0??00?00????

?????200??1?????????????????????0????????????????????????????2?000000000?10?1

0??0???????010?????00????0?????????????????0000000???0?001011????1?0???00?0?0

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00???11?10?00000000?????????????0?????????????0000??00?0?0000?0000001[01]00?

0?????????????????0?????????????001??01?0?0010000?000000000000??0?1?010?000000

00?0000000???0?0000???00?0???????0?000000004?00000??100??00??0000?1????????0

0??????000?????????

Troodon formosus

???1?1112?1101000001???0?011?0??????2022000021 0?00?1?01100????0?10??001??????

????0111010100???1111100101111111?1000?1020??11?????????????1?010????0?000010

??????????0?0?2?10?11000?0??01111000???000100000 21??01????000??1?0??010???1??

0??0?0?00000?0?0???000???????

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??0?????0000010100 1??

0???1110?1???????

Saurornithoides mongoliensis

?01??1?1??1101???0?110001?1000????????2?????????????????????1?010?100?0010??1??

??0001110101?????????1???0??1?????100??1?????????????????????????????????????

??????????0101201 0?010??10?1?11110???????????0???10?01??????0??1?0???????????

010??00000??0?1?01?0???0??00??

0000???????0??000000?????0??1000?0??0???????????0000???0?????00100?00?1??????

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0???1110?1???????

Saurornithoides junior

?01101?12?110100?001?000??100000????2022000?21??0????11100??????100?001???1??
??000111010100?????????????????????1?1000?1020?1?????????????????????????????????
???????????1?????????????????????????????????011????2???????????00??00???11??????
??0??000000000100000???10???0???
00?0???????00?00000??????0001??0?00?????????????0000??0?00?????????0001[01]00?
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????????????????????????????????1?0001000004??000????2????0??0???00000101001
?11???1110?1???????

Byronosaurus jaffei

?????101???101?11001100010l1?0??????20220????????????1?100??????0000001??11??
??000211??01?0?0???????010111????????0??02????????????????????????????????????
????????????????????????????????1????0?0??0????????21??????????0????0????1??????
?????00000000?1?00????????????????????????????????0?????????????????????00?0???
0000??0????00000000?????????????????0?????????????????0?0????0?????0010???????0????
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????????????????????????????0000?0????????????????????????????????????00010001l??
0????????1???????

Sinornithoides youngi

?0??01?????????????????1?000??1??0????00???2????????1?0??????????????????00??0010?????
??0001110?01??????11??001?????????????0011?10112101????1?00?1?101?0???10000000??
??21??01??01??30???11?0??001??1110?????0????1?000110001?0??0?0?1??00?0???0???0
010?0??00000????0??0?????????????????????????????????0?????????????????????????00

0??0?0?100?0000?000?????????????????????00?????1?00??000??????????0?01[01]00?
00????????0???0?1200??0?00000?0???1000???0?1000???00?0??????????00??010?000000
???000000????00??0??1000??00?????10000000001400000?0020?020000000000????????1
01??????1?010100??1

Sinovenator changii

?0???0002?000011110010101?1110?011?02??2??0011???011?10100????0?000?001??????
000001111O?1?????11?10100011110?00100011022l?1?????????110111??????1000?0???
0?211?010111[02]0301?11102112O1?11110000??10011000111??110?000000???0000110001
000110000000??1??011?????????????????????????0????00?????????????????0??0000?
0?0000??0??0?000000000000??0000000?00?0??0000010100[12]00??0000?0?00100000001??
??????????????????1200000??00?0100??10?????????????????????????????????????
??????????001?1100000000100?00000001000000000?4?0?00?00020?0100?0000000001000
10?10??1011000???????

Mei long

?0????????0????????11010?????0?11?00201210000l?10?110??100?????00010010??1?0
000?021???01?00110111000l1?1110?01???0110221111?11???111?11100?0?1?10000001?
012111?1??1100301?1110211???0111100?0101001000??110011?0?0000???00000??000100
?1??0?0?000000?001?0??????????????????????????00?????????????????000???0?0?
000001010O?00?00000???????????00?0??0??00??0101????????0?0?000010000001[01]00?
00????????0110001200?00?00000?00101000?0?0000000?0000000?000?01??1?0???000000
0????00000??10000001??00?0000??000000000000400?000?0021?01000000??0???100??1
010??101100?1100?10

IGM 100/44 (EK Troodontid)

?????0012???1??0???????????????1??11??
????????1??????0???10?000000?

??01?1?001???00??????0?0??1??????

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??1?1????????????????????????????????

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Jinfengopteryx elegans

?0????????????????????1?01???2000????????1??00?0????01????100??????00?00??0??1??

0?000?1???0???1?????????????????????????02????1?200?1?????1101110??????1000000??

???1?????????????????????2??0??????????0????????????????????0?0??00????00??????????

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?0?????100??0?00000?????????????????????????????????0??????0?0?00???0?0??00??0?00

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??00?0000???????????0?

?11?01???????????

IGM 100/1126

?0????002?0000?11[12]01?010??2000?011?02012100011 0?0?10010100??0??000000000?11

?000000211??00?0?????????????????????0????01102?????????????????????????0??1000000

1???211?010?0100201000101210 12??111000????0??2?00121000 1?00000011?00?0?020000

?00100?0000000111?01?0????????????????????????????00?????????????????????0?00???

0?0030???????00000??0??????0?0??00?00?0??0??0000000?00???0?0?????????????0???

??0?00???0?000?

???0100000???00??0??1??0????00?0???0?????00???1?000???20?02????00000010100111

??0??101?001???????

IGM 100/1323

?01???????0???11???1?000??20000?1??020121?00?1??0???0??????00?0?000?0????1??0
0000021???0000?????????????????????????011?????????????????????????????????????0
0??1??????010?20100[12]102?1011???????00???0????0??2???01??00??0????0?0???00?0
?00100?00000000?1?01?0?????????????????????????????00?????????????????0?00???
??0030???????00000??00?????0?0?000?00?0?????000000?000??0?00?????????????????
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????????00???????00???00????0?00?????????????1000????2?????????????????????
??????01???????????

Segnosaurus galbinensis

??1??10?0000?0
00???01000001?????????????????????1???0?????????????????????11???00????????010?2
0021?0000?1100211?0?1020?0??????????00??0?000?0000?21?0??00????1??0?0???00?0?0
0??0??0??????
????????0?????????????????0?????????????????????0?0????0????????????0?????????
??????????????0?0???????0????00??
??????001?1?000???10100??0????000?00??0??000000000000??2??0????00???????????
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Erlikosaurus andrewsi

?0110??02?0?1?0??1010011100??0001?100000100001000?0??00000??111121001000000 20
001?00100000 1???0?????????????
??0?00?0??????00??01??00?0?00??????
??????0?00001010010???000000?1??
0000????0??000000000000111???10?0100???000000000000??0000?????????????????
????????????????????????????????????0?0010000?001000?000?????????????????????

??0???0?0100??0?????0000?0????000??
?0?000?0?????????

Alxasaurus elesitaiensis

??210?100??????
??????100?001??????????0?01010000?1?000??02?0?1?????????????00000?100?000012
0021?00?01010?211?021?2??????01????00????????00000210000??00??1??00?0??00?0?0
0??00??
??????0?????0????????????????????????????????????0??00?????0??00?0?0?[01]?0?
??????????????????0?00????????0??00???????????0?0???0?????????????????????000000
???000??0000000?0????0???0
??????????0????????

Tyrannosaurus rex

?10000?0110000100210000010101000000011010010211000010010001?00000000010011001
000000001010110100000?000010100000010000?001000??1????000000010000??0??10001
031000100000001011011000000 1?010010000?000100000200000001000000000000000?0?0
010100100000011000?011111110111111111110011001011122111111011111111111011111 1
112110201120000000000000000000000?0000??000001011000??0000?000011000000[01]00?
00????????00?00002000 10?000001000111 01?0?0010000?000000000000100??0??????000
0???00??001?000000001000002010000000000000040000001010 0?00000000??02000??000
1?0??00100000110?00

Tarbosaurus bataar

??????????????????0??????????????????1????????????????????????????????
??0??????????
??2????????????????????????????
????0??????????????1111111011111111101001101111112211110101112111111011111?

1121??2011?00000000000??000?????0000???000?????????????00?????????????????????
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??000000??02000??0001?
0??00100000??????

Albertosaurus sarcophagus

?1000??00?0000?002?0?0001O??100?0000110100?021?0??0?00?00000000?0??????0?1???
000000001010111?????0????001?10??0????000??0???????????00000010000????010001
031000100000001011011000000??0?00?0000??00100000200000001000000000000?000?0?0
010?00100000011000?011110111100000000001000000011011110101012000111111010101?
112110201 1?0000000000???000000000000??00000101??000???000?0000??00??????0??0
????????????0??20?010?00000100O?1101?0?0010000?000000000000?0??0??????00?0?
??00??00???00000001?00??2?1000???00000000??000000???00??0000000??02000??000??
0??00100000110?00

Gorgosaurus libratus

?10000?00?0000??0?1000001010100000001101O0?021100?0100100000?0000000100?1001
000000001010110100000??000101000000100000001O000?1000100000000100000000?010001
031000100000001011011000000100100000000?000100000200000001000000000000?000?0?0
010000100000011000?011100111100000000001000000111011110101012000011111010101?
11211?2011?000000000000?000000000000???00001???0000???000?0000??00??????0??0
????????????00?20?010?00000100O?1101?0?0010000?000000000000?0??0??????00?0?
??00??00???00000001?00??2?1000???00000000??000000???00??0000000??02000??000??
0??00100000110?00

Daspletosaurus

?11000?000000001002?000001010100O0?00110100102110000100100010000000000100?1000
000000001010110???000???001?10??0????000??0???????????00000010000????010001

03100010000000101101100000??0100?0000??00100000200000001000000000000000?0?0
010?00100000011000?011111110111111111010011011011222102101011101111111011111?
11211?2011?0000000000???000000000000???00001?1?0000??0000?0000??00??????0??0
????????????00?20?010?00000100?1101?0?0010000?000000000000?0??0??????00?0?
??00??00???00000001?00??2?1000???00000000??000000???00??0000000??02000??0001?
0??00100000110?00

Eotyrannus lengi

??????????????????????000?0???0??????100????????????00????????????00??010??????
??000000101O?1???00000001?0?0??????????
??0????0??????0????0?00????00?0?????0??
????????00??0??00??0??????????????0111?101??00111????????0?0?????????????????
10??????1??0000?00?????????????????0??0?000000???00???????000?????????????
????????????????00000?0?????0000?0?0?????1000???000000?????01?????????000??
??????????????????????????????0??????????????????????0?????????????????
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Dilong paradoxus

?0100??0000000?10010001O??101000010011010000100000010?0000?????0000000??00?0
000000001010111000l?0?0100??1?0???????0??012[01]0??????????000000110000?????0000
?00001??10??0010100?0?0?0100000000000?00??00010?00100?0000?00000?0?00000?000?0
?00100000000000111O0?0??00???00?????????????0????01?????????????????110??00?
??000001010??00000000??????01000?0?000???000001?100000???000???00?000??01????
?0?????????????1200?00?0?0?0000001000?0?0?1000???000000000??0?00??0?????1000
0??00000001?0??0?00?11000?2000000000000000004000000?????????0000?0000?0?10000?
??0100000000????????

Shenzhousaurus orientalis

???0?????????????????21001?1000??1???000??00?000?00?????????????0?00000000??0??
0?1?12?0??1?????????????0????1???0???00000??[012]0????????????????????????????001
0000001??110?0000100?000000100??00001?0??????????????????0??1??1?0011????00?
??0010??0000001?????????????????????????????????????0?????????????????????0???
??000????0???000?00000?????????????????????00?????0??????0?0?0?0?100?0001?00
?00???0??
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Ornithomimus edmonticus

?01010?110?101?10102100010101010110000000000000000010000000?????000000000010?1
001?1???????0?001?10110000101000101000000001001001????0112000200000?102001
0000001100001010010000001001000001100010001000020??00?011111110121110000?0?0
010001000000001?????????????????????????????0?????0?????????????????????1000?0??00
00000001l0?0?0000000???????????0?0?10???0000000?0??????000?000010000001[01]00?
00?????????????0?00??0?0?0?0?00?11001?0?00?000???0000000??00????????1??0?0002
0??00000201?0000?00010000?2000000000000000004?0??0???????0??0??000?1???????0?
??0??0000000???????

Archaeornithomimus asiaticus

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???000?1100001010000?00?00100100000l?000100010000000?0?00001?11??10??1?1??00?00
?001000???
??0?0010000?01[01]0
0?????????????????120??00?00000?0?1???01?0?0010000?000000000000?00000???0??0
0000??00??001?0????00?1?000020000000000000000004?0000?0?100?0?00?000??????????
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Anserimimus planinychus

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Huaxiagnathus orientalis

?01?0??????????????0001???1???0?????00??0???????????????????????00?0010??????

??00010?1010?00??0???1????????0??????00???02100010????000000000?00??001000000

0020?0??000000100?000011?0???0??????0??0?010000000?0?011??000???00?0??00?0?0

010?0000000???1?00???????????????????????????????0???????????????????????????

000????100???000000????????????00??????????????????????00??00?1??0??00[01]00?

00????????0000000200??0?0?0?0000100??????10?0???0????????????0???????0010?0

???000??001?00???00000000??0????0?0?000?0????00??0????0????000000000????????0

00????00000?0?00??1

Sinosauropteryx prima

001?0??????????????0001???1???0?????0000??????00??110????????????00??01???????

??0001001010?00??01??100????1?0?0????00?1100100010?????00000000?10??0010000?0

0020??????0000100?000?11?0?1?00?0??000?0?0100000000?011??0000??000?0??00?0?0

00??00000000??1?00?0???????????????????????0??????????????????????????????0?00

00?????100?00?00000???????????????0?0???????0101????????000?0?0??0?00001[01]00?

00???????????????1?00??0?0?00???0?1?00???????0?0???00?00????????0????1??0?0000

???0000000?00?000??100?0?20?????00?00??0??0400??00???0???000000000?????????0
00?10???000????????

Compsognathus longipes

?01?0?????????????????0010??1??00?0?00000????011???0??000????0????00000100?1?00
?0000100101010?01??00[01]0???1?0?0???000?01011000?1??????0?000000?10???0???00
?00??????????0000100?000?01?0??????????00?000100000000000?1100?00????0?0???00?0
?00100000000000?000000??????0??0?00?0?00??0????00?0????????000?????0??00?0?
??0000?10100?00?000000??0?00???0?0????0???0000?????1?0??0000?000?10000000[01]0
0?00????????00??0?1200??0?0?0?0?00??100????0?1000???0????0?????????????????0000
?????0?0??001?0???000?00000??0?????00?00??0??0?000?00?0?00?000000000000???????
?0?????000000????????

Jeholornis prima

10????0?????????1???0???0?????001?????????????????????10???????????0000?1???00?0
0?1?1?????????0????????0????1?0?11???02111021??01?0???0110311100?1??110000010
11?1??0??01?0???1???1?211?10???????01????0101101003000000000??0??1000??00?010
????1???000?1?????0?????????????????????????????0?????????????????????0??????
?0???12200??1001000?????????????????????0????00000000??00?0?0000010000010000?00
??001???00000?1001000?0?1000110000100?0010000?000?0000?0000100000101110000?
000000000010000?0000?0000?10100?000000000101000001001000?00000001100????????011
?1110???1?1100?10

Jixiangornis orientalis

101?????????????????0010?????001????0?0??00000????????0100??????000001????0?0
??1??0????????00?0???1?00????1??20???02??1021??11?1?000110311100011010000011
112101010211000010101?211?10?2?11?001??1?01[12]1101003000?00?000?0??1000??00?0
100??110?001?1?????????????????????????????????????00?????????????????0?0????

000000?12200??0001??0?????????????????????????0?????000??00?0?000?11?01?01100?
111?0?????000000100100?00100111100010?0?0000000?000???0??0????10??010?000100
0??0000?00011000000?10?000????00002?0??000001110000001?000?0000?001100????????0
0??11????01?1100?10

Yanornis martini

?01?????????????????1?010?????0?11???0??2??0????????0?0???????????0000011???0??
??000?1???00??0????1???0????????4?1???????03??????110?01103111 0?011?113001 0??
??????????????????????22?010?2??10??1??0?0121[23]0000300000??0001???00?0??????
?0???21?0?0??
?????????200?10001?01?????????????10????????1?????????????????0?0011?030???0??
?0210?[12]??10100001011010?1?11?1111000111??0101?0101?10000?0?????1021[01]10131
11[01]01100[01]100?0??01?0??0???001??1?????2??0??00?11[23]110[01]?12??00??1?0??01
100????????01??1????????1100?11

Apsaravis ukhaana

??????????????????????0?????????????????????????????????????0002?1?0??0??
??????????????1??11??10200??1???5?100021??23???????1?0101103110000111113003??0
00?1???1?200000?1?021?2220??12?010?????1??1213010 0?00000??20???1?20?0?????0?0
0??21??2???????????????????
???????200??10?????????????????????????0?1[01]??????1?0????????1?20010?[01]401001
1???21??1?????????1001000?0?10001111011111?01011010[12]0111110000101102111 0?[23
]11201100?11??201?11[01]00101111111?1110??2?10121121131111 1?201000?1?0??01101??
??????011??????0?1????????

Yixianornis grabaui

101?????2?021??1?????0?01????0?1?1?0?????????????1????0100??????000?010???0?0
0?00120???10?01???1???0000??1?0?40??0???0023???11?1100011031110?0010113000010

0021?101?211003010001022222??0211?0??1??????2130100100000??000?0??1000?20??0?0

00001???????????0??0?????????????????????????????0?????????????????????????0?00

??00?12200?10001???????????01??1????????11[01]??????1?0?????10??2001100301???11

1021??[12]??10100001011010?1111011111001111100?0110???01?000???0?011021[01]10?31

12001100[01]100?0000100?00???001?21?101?2???????1113110[01]?1???00??1?0?001100?

?????00011?11?01????0100?10

Sapeornis chaoyangensis

?011?????????????????0?010??11000????00??21?0?00??????0??????0????0000010??10?0

0000020??????00????1???000????0?211??0210003??100?????2110111101001110000010

1121??00?211000?101[01]00211210????1??01??1001210?10030000000000????2000??0??0

100??0100?000???1???00?????????????????????????????0?????????????????????0???

0?0000??2200?000000000?????????????????????????????0?00???000?0000010010000010

?0?????????00[12]0000200000?00000?0000001000?0?01010?0010000?0???0100?1[01]10?11

11000??0[01]00?000000?000000?000???000?0?0?00?00??00000001O??00??0?00001000???

?????001?1?1011?1?1100010

Neuquenornis volans

???????12?????????20?????????????????????????????00???????00?????????????????????

??????????????????????????00?????????????????????1?11011?1031110?011111000????

?????????????????????????????????010???????????[01]010030??0????0??????0?00?????

??????1???0??????

????????0100???0110??????????

??21?????101110?1?01100?001?001?0???[12]??1???01?0???0?????[01]???????????2???21

0?1???01?????????????????????????110?1?1?0????????1?[01]?0???1?0111???????0?000???

10000110???????????????

Patagopteryx deferrariisi

?0??0010??????????????????????????????
??????????????????????2???0?1??????????
??211101?????????????????????2?010001??10012130100l?000???????1????????00?0??
???1???1?????????????????????????0?
??????0?????????????????????0?0?1??????00??111110000????????10100000030????????
????0?????????10010????0101?11110[01]00???[01]?10?0???01000001[01]0001??[12]00???
3?0????????00?20001000?0111011?2?0????20?0?000[12]113100110000000?[01]?0??0?10
0?1?100??01?0???0?001????????

Cathayornis yandica

?0??????????????????1?010?????0?1??????????0?????????????????????00???????????
??00001???????0????????[02]????????3?????2????3???0??11?02?1031110?011?11300?0
?01111?0?00?11000?101?102122??????????1???0??[12]1[01]1?0?3000?0???00????0??1??
0??0100???100?????????0??0???
????????????2200?[01]0?01??1?????????????????????????0??????0?????0111??20
1?0?10??20??1??101210?11011????010?01100001001011O[01]?01020111110?[01]?1??1???
2101210?1?1?01?0101001?1?0?000??000?11???11[12]0?0?0?1[01]1?[01]?0??????0??????0
??01110????????01????????01????????

Concornis lacustris

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??????????????????????????00?????????????????????0??11?02?1031110?0?1??1?0030??
??????????110?101??11?222???0???1???1???0?1[02]11??0?3000?0???0?????????????????
?001??1???
????????2200???0111????????10
??20??1?01012100110l1?0?0010001?0???[01]001?110??0102?1???10???1[01]1??[12]?????
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110?????????????????????1100110

Gobipteryx minuta

?0??????????????????1?01010?0?0?????????????????????????????????11?000?0????????

??1?1???2?????????????????????

??11?????????????????????????????

???1????0???

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0???????????121??1101000?0?1000110?00[12]001?1?0110???0?????????????11?121??[012

]?0??????1?0??1???????????0??001???0????1?10?00111111000?11?111?0??????????????

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Vorona berivotrensis

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Songlingornis linghensis

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??0????0?????0?????00????????

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??21??[12]?0001[01]00?10110???1?11011??

??0??0?????????

????1??1???????????????

Hesperornis regalis

?0?????????????????00010100?00?????00021?001????00?0???00????1?000?001???1?0

001?021???00??1010111O?2100??11?50100?210?23??11??10??00103111???????????3??0

202100?1??00000???0210222O??12???0001??11?1213110010??0?00??01?1?0000?000???0

0??2??0?1111????0??1?0????00

00???10?1??10?111111200l?1?0?1010??1110011100??00?0???10101121011005010011?1?

0?00010010?0?01??0?10?0???000010??0?????????0???0????0????????????????????

??????201?111000011111112111021211111002113111122210220O2?0?????00??????0001?

0???0?000?0100?11

Baptornis advenus

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??212????????????????????????????????

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???????????[12]?????????????????????????11001??00??1??????????1121011004010011?1

1????012?0??????1010?10?0???000?????0?????????0???0???????????01??[01]1[01]?????

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Ichthyornis dispar

?????00????????1220?????????????????????000111???1?10???????????000??1?????10

00??0210??10???1?01111?2100?1???5?000?21??33???01?100?00103111O?0111113003??0

102?1??1021100O????210222???12??10011??11?1213110???00?0??20?????00????0??00?

???21???????????0??

????012200?[12]0?11????????0??????10[01]1?11101110100102O???101?01200111?[45]110
021[12]??21102201010000101101O?1111011111101111001011011101000010[01]101112111
12311201110011?1200011[01]00101??11?121110212111110021131111[12]2?21000002?0??01
1?100?10???0110??1??00?00100?11

laceornis marshi

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??1101?010311?????1113?03???
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21?02[23]11????11101101O?111101111?01??????????????????????????????111311401
11101110200011O??1?111?11121110212?12110021 1????????????????????????????????
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Limenavis patagonicus

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??011?113??????
??20????????????????
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??10000[01]010101101 1?11[12]3113
0111?011??
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Crypturellus undullatus

10????012?020002?2001010100?00?111?12002100001011110000 10???1?10000?000??10??
001?1?????????1110111122100?01107?110??12?23??121?11010010311011011111 3003??0

01210001?20120111002102222??12?0100010011012130 1?0???0100020001?20000200?0?0
01021???120??01??????????????????????????????????0????????????????????????????0?
000001020 0?211211211[01]0101000111110101100110111111111001010112101011621011 12
21211112?1010000121101101011111111001111101100012011000011101011011111031140 1
10111110201?11201101111111211102121021100211311122221[01]0010100??011?10101000
001111110000??1100?10

Lithornis

101??????????????????01010100?00?111??2?02?00?0????????????????????10000?00????0??
101?1?????????1????????2????????[67]?1????????????[12]??11000010311110011?11300
3??00021010 1?20100101??2102?????12?01000???11?12130100?????0??200?01?2010???0
?0?0???21???12??????????????????????????????????????00????????????????????????
??0?00000??200??11211211 00?0100011111010110?11[01]1101?1111?01?101121012?0[56]1
1?1?1[12][12]12111221101000?10110110111101111?01111100110001[12]1110000101010110
111111311301110[01]11102[01]00?120110111111121110212101100021131112222110010[01]
?000011?1????????011?111??00?????????

Gallus gallus

101???102?021002?20000101 00?00?111?120021?0001?10100000 1????1?100100000000?1
101?1?????????101[01]1111221?0?01007?120??12?23??1[12]1?11012010311020011111300
3??00121111 1?2?10011100210222??12?0100011011??213010010001000200100?20100200
?0?0???21???121??01???0????????????????????????????00????????????????????????
??0?0000010200?11021121121111111221101111111111111011000110101111210101162100 1
11[12]12111121101200012110111111111111100111110110001201100001011101101111113 1
14011001211021??11211111111111211102121021100211311132222100111?00?0110001010
000011111 1?000??0010110

Crax

1011011?2?021000??001010100?00?111?120021000011101000000100??1?100000000000?1
101?1?????????10001111221 00?111?7?120??12?23??121?11002010311121011111 3003??0
002100?1?2?10011100210222 0??12?0100011011?121301001000100020 01?1?20100200?0?0
???21???121??01?????????????????????????????????00?????????????????????????0?
0000010200?2102112112111111122110111111111111011000110101111210101162110111 21
211112110120001211011111111111111001111101100012011000010111011011111131140110
11211021??111111111111121110212102110021131113222210011000000110 00?010000011
11110000?11100011

Anas platyrhynchus

101???102?021002?21010011 00?00?111?10002??00?1?10100010?0???1?10200000100?011
101?1?????????101?1111221?0?011?7?11???10?2310121?11011110311111011111 3003??0
012000?1?2?10011100210222 1??12?0100011011?121311?0???0100021 01?1?20100?00?0?0
?1021?0?121?????????????????????????????????????00?????????????????????????0?
0000011200?2102112111111111122110211121111110110001111011112101010621101112 1
211113120110011011010?1[01]11111110000111001100012011000010111011111111 2311401
10101110 21??111111011111111111011210211002113111[23]22210001020 0?0011?10?01000
00111111?000??0100?11

Chauna torquata

001??1012?0210002?10101010 0?00?111?100021?000101010001010 0??1?100000000??0011
101?1?????????10111011121 00?111?7?11???10123121 11?10000010311111011111 3103??0
012101?1?2?100101?02102222 0??12?0100011011??213010010000000200 101?20100000?0?0
?1021?0?121??01?????????????????????????????????00?????????????????????????0?
0000012200?110211211[12]11111102211011112111111101100011110111121012106211011 1
112111140101[01]00110110111111011111010211100110001201100001011101101111123114

011011111021??11111111111111211102121021200211311122222100100000000110001010001011111110000?11101?11

Hongshanornis longicresta

101????????????????11010?????0?11???0????00??????1??????????????000?001??00??
??1?1?10???0??0??01??1?0????????[234]??????????3???1??11?0111031110001111130020?0112???01?20????????2??2222???2??100?1??????21[23]01000000000?000?01?1??????
??0?0????1?0?0??????????????????????????????????????0????????????????????????
???000000?1?200????010?1?????????????????????????????00??????1??????0?????1??
?1110????????011?0?1?111???0?10???110000111???110???2????0????????1????1??210
000??000100?01?1?0?0??0??00?????????2????1???11[23]100??[01]??100??2?0???1?????
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Liaoningornis longidigitris

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??3??1??0????????????
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11?01?????????????0???0??????????????????????????????0?????01????2???????????
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