Phylogenetic relationships among coelurosaurian theropods

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Abstract
Birds are a group of coelurosaurian theropod dinosaurs, but relationships among coelurosaurs remain controversial. Here we present the results of an analysis of 42 species previously classified in the Coelurosauria, the most taxonomically comprehensive study of this group yet published. Based on direct examination of specimens of nearly all of these taxa, we coded 205 characters derived from previous studies and our own observations. Our results resolve relationships among major groups and corroborate most elements of the hypothesis of Gauthier (1986) in finding a monophyletic Coelurosauria and Maniraptora (that is, Ornithomimosauria is the sister group to other Coelurosauria and tyrannosaurs are outside of this group). *Ornitholestes hermanni* is the sister taxon to the remaining Maniraptora. Within this subclade alvarezsaurids are the sister group to a bird–dromaeosaurid and troodontid–therizinosauroid–oviraptorosaur dichotomy. Support is found for a clade containing therizinosauroids and oviraptorosaurs, which comprise *Chirostenotes pergracilis*, *Microvenator celer*, *Avimimus portentosus* and *Caudipteryx zoui* along with the oviraptorids. The resolution found here shows that composite coding of higher level terminals is not required to recover phylogenetic signal, and we suggest that composite taxa be avoided in future studies of coelurosaur phylogeny.

Keywords
Alvarezsauridae, Avialae, character sampling, Coelurosauria, exemplar, groundplan, higher taxa, missing data, Maniraptora, taxon sampling.

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Appendix 1: Character descriptions

All characters are unordered unless otherwise indicated.

1. Vaned feathers on forelimb symmetric (0) or asymmetric (1). 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.

Openings of the skull

2. Caudal margin of naris farther rostral than (0), or nearly reaching or overlapping (1), the rostral border of the antorbital fossa (Chiappe et al. 1998).
3. Narial region apneumatic or poorly pneumatized (0) or with extensive pneumatic fossae, especially along posterodorsal rim of fossa (1).
4. Pronounced, round accessory antorbital fenestra absent (0) or present (1). 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.
5. Antorbital fossa without distinct rim ventrally and anteriorly (0) or with distinct rim composed of a thin wall of bone (1). A rim is most strongly developed in the therizinosauroid *Erlikosaurus andrewsi* (Clark et al., 1994) but is nearly absent in ornithomimosaurs.
6. Accessory antorbital fossa situated at rostral border of antorbital fossa (0) or situated posterior to rostral border of fossa (1).
7. Tertiary antorbital fenestra (fenestra promaxillaris) absent (0) or present (1).
8. Orbit round in lateral or dorsolateral view (0) or dorsoventrally elongate (1). It is unclear that the eye occupied the entire orbit in those taxa in which it is keyhole-shaped.
9. Anterior process of postorbital projects into orbit (0) or does not project into orbit (1).
10. Postorbital bar parallels quadrate, lower temporal fenestra rectangular in shape (0) or jugal and postorbital approach or contact quadratojugal to constrict lower temporal fenestra (1).
11. Suborbital fenestra similar in length to orbit (0) or reduced in size (less than one quarter orbital length) or absent (1).

Braincase

12. Otosphenoidal crest vertical on basisphenoid and prootic and does not border an enlarged pneumatic recess (0) or well-developed, crescent-shaped thin crest forms anterior edge of enlarged pneumatic recess (1). This structure forms the anterior, and most distinct, border of the "lateral depression" of the middle ear region (see Currie 1985; Currie and Zhao 1993a).
13. Posterior opening of basisphenoid recess single (0) or divided into two small, circular foramina by a thin bar of bone (1).
14. Crista interfenestralis confluent with lateral surface of prootic and opisthotic (0) or distinctly depressed from lateral surface (1).
15. Exits of cranial nerve X–XII flush with surface of exoccipital (0) or cranial nerve exits located together in a bowl-like basisphenoid depression (1).
16. Basipterygoid recesses on dorsolateral surfaces of basipterygoid processes absent (0) or present (1).
17. Subotic recess (pneumatic fossa ventral to fenestra ovalis) present (0) or absent (1)
18. Basisphenoid recess present between basisphenoid and basioccipital (0), or entirely within basisphenoid (1) or absent (2).
19. Parasphenoid not highly pneumatized (0) or base of parasphenoid expanded and pneumatic (parasphenoid bulla) (1).
20. Basipterygoid processes ventral or anteroventrally projecting (0), or lateroventrally projecting (1).
21. Basipterygoid processes well developed, extending as a distinct process from the base of the basisphenoid (0), or processes abbreviated or absent (1).
22. Basipterygoid processes solid (0) or processes hollow (1).
23. Depression for pneumatic recess on opisthotic absent (0) or present as dorsally open fossa on prootic/opisthotic (1), or present as deep, posterolaterally directed concavity (2). 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.
24. Accessory tympanic recess dorsal to crista interfenestralis absent (0), small pocket present (1) or extensive with indirect pneumatization (2). 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 authors (e.g., Walker 1985).
25. Caudal (posterior) tympanic recess absent (0) present as opening on anterior surface of paroccipital process (1) or extends into opisthotic posterodorsal to fenestra ovalis, confluent with this fenestra (2).

Appendix 1, continued.

Rostral bones

26. Maxillary process of premaxilla contacts nasal to form posterior border of nares (0) or maxillary process reduced so that maxilla participates broadly in external naris (1), or maxillary process of premaxilla extends posteriorly to separate maxilla from nasal posterior to nares (2).
27. Posterior premaxillary process short and blunt (0) or elongate and extend along nasal-maxillary suture posterior to nares (1).
28. Internarial bar rounded (0) or flat (1).
29. Premaxillary symphysis acute, V-shaped (0) or rounded, U-shaped (1).
30. Crenulate margin on buccal edge of premaxilla absent (0) or present (1).
31. Secondary palate formed by premaxilla only (0) or by premaxilla, maxilla and vomer (1).
32. Palatal shelf of maxilla flat (0) or with midline ventral "tooth-like" projection (1)

Jugal, quadratojugal, lacrimal, squamosal

33. Jugal and postorbital contribute equally to postorbital bar (0), or ascending process of jugal reduced and descending process of postorbital ventrally elongate (1).
34. Jugal tall beneath lower temporal fenestra, twice or more as tall dorsoventrally as it is wide transversely (0) or rod-like (1).
35. Jugal pneumatic recess in posteroventral corner of antorbital fossa present (0) or absent (1).
36. Medial jugal foramen present on medial surface ventral to postorbital bar (0) or absent (1).
37. Quadratojugal without horizontal process posterior to ascending process (reversed "L" shape) (0) or with process (i.e., inverted "T" or "Y" shape) (1).
38. Jugal and quadratojugal separate (0), or quadratojugal and jugal fused and not distinguishable from one another (1).
39. Supraorbital crests on lacrimal in adult individuals absent (0) or dorsal crest above orbit (1), or lateral expansion anterior and dorsal to orbit (2).
40. Enlarged foramen or foramina opening laterally at the angle of the lacrimal, absent (0) or present (1).
41. Lacrimal anterodorsal process absent (inverted L-shaped) (0) or lacrimal T-shaped in lateral view (1), or anterodorsal process much longer than posterior process (2). Ordered.

Prefrontal, frontal, postorbital, parietal

42. Prefrontal large, dorsal exposure similar to lacrimal (0), or greatly reduced in size (1) or absent (2).
43. Frontals narrow anteriorly as a wedge between nasals (0) or end abruptly anteriorly, suture with nasal transversely oriented (1).
44. Anterior emargination of supratemporal fossa on frontal straight or slightly curved (0) or strongly sinusoidal and reaching onto postorbital process (1) (Currie 1995).
45. Frontal postorbital process (dorsal view): smooth transition from orbital margin (0) or sharply demarcated from orbital margin (1) (Currie 1995).
46. Frontal edge smooth in region of lacrimal suture (0) or edge notched (1) (Currie 1995).
47. Postorbital in lateral view with straight anterior (frontal) process (0), or frontal process curves anterodorsally and dorsal border of temporal bar is dorsally concave (1).
48. Dorsal surface of parietals flat, lateral ridge borders supratemporal fenestra (0) or parietals dorsally convex with very low sagittal crest along midline (1), or dorsally convex with well-developed sagittal crest (2).
49. Parietals separate (0) or fused (1).
50. Descending process of squamosal parallels quadrate shaft (0) or nearly perpendicular to quadrate shaft (1).
51. Posterolateral shelf on squamosal overhanging proximal end of quadrate absent (0) or present (1).
52. Descending process of squamosal contacts quadratojugal (0) or does not contact quadratojugal (1).

Quadrate, occiput

53. Dorsal process of quadrate single-headed (0) or with two distinct heads, a lateral one contacting the squamosal and a medial head contacting the prootic (1).
54. Quadrate vertical (0) or strongly inclined anteroventrally so that distal end lies far forward of proximal end (1).
55. Lateral border of quadrate shaft straight (0) or with lateral tab that touches squamosal and quadratojugal above an enlarged quadrate foramen (1)
56. Quadrate solid (0) or hollow, with depression on posterior surface (1).
57. Foramen magnum subcircular, slightly wider than tall (0) or oval, taller than wide (1). See Makovicky and Sues (1998).
58. Occipital condyle without constricted neck (0) or subspherical with constricted neck (1).
59. Paroccipital process elongate and slender, with dorsal and ventral edges nearly parallel (0) or process short,

Appendix 1, continued.

deep with convex distal end (1).

60. Paroccipital process straight, projects laterally or posterolaterally (0), or distal end curves ventrally, pendant (1).
61. Paroccipital process with straight dorsal edge (0) or with dorsal edge twisted rostrolaterally at distal end (1) (Currie 1995).

Palate

62. Ectopterygoid with constricted opening into fossa (0) or with open ventral fossa in the main body of the element (1).
63. Dorsal recess on ectopterygoid absent (0) or present (1).
64. Flange of pterygoid well developed (0), or reduced in size or absent (1).
65. Palatine tetraradiate, with jugal process (0) or palatine triradiate, jugal process absent (1).
66. Palatine and ectopterygoid separated by pterygoid (0) or contact (1) (Currie 1995).

Mandible

67. Symphyseal region of dentary broad and straight, paralleling lateral margin (0), or medially recurved slightly (1) or strongly recurved medially (2).
68. Mandible without coronoid prominence (0) or with coronoid prominence (1).
69. Dentary subtriangular in lateral view (0) or with subparallel dorsal and ventral edges (1) (Currie 1995).
70. Dentary symphyseal region in line with main part of buccal edge (0) or symphyseal end downturned (1).
71. Labial face of dentary flat (0) or with lateral ridge and inset tooth row (1).
72. Posterior end of dentary without posterodorsal process dorsal to mandibular fenestra (0) or with dorsal process above anterior end of mandibular fenestra (1), or with elongate dorsal process extending over most of fenestra (2).
73. Nutrient foramina on external surface of dentary superficial (0) or lie within deep groove (1).
74. External mandibular fenestra oval (0) or subdivided by a spinous rostral process of the surangular (1).
75. Internal mandibular fenestra small and slit-like (0) or large and rounded (1) (Currie 1995).
76. Foramen in lateral surface of surangular anterior to mandibular articulation, absent (0) or present (1).
77. Splenial not widely exposed on lateral surface of mandible (0) or exposed as a broad triangle between dentary and angular on lateral surface of mandible (1).
78. Coronoid ossification large (0) or only a thin splint (1) or absent (2). Ordered.
79. Articular without elongate, slender medial, posteromedial, or mediodorsal process from retroarticular process (0) or with process (1).
80. Retroarticular process short, stout (0) or elongate and slender (1).
81. Mandibular articulation surface as long as distal end of quadrate (0) or twice or more as long as quadrate surface, allowing anteroposterior movement of mandible (1).

Dentition

82. Premaxilla toothed (0) or edentulous (1).
83. Second premaxillary tooth approximately equivalent in size to other premaxillary teeth (0) or second tooth markedly larger than third and fourth premaxillary teeth (1) (Currie 1995).
84. Maxilla toothed (0) or edentulous (1).
85. All maxillary and dentary teeth serrated (0) or some without serrations anteriorly (except at base in *S. mongoliensis*) (1), or all without serrations (2). Ordered.
86. Dentary and maxillary teeth large, less than 25 in dentary (0) or moderate number of small teeth (25 to 30 in dentary) (1), or teeth relatively small, and numerous (more than 30 in dentary) (2).
87. Serration denticles large (0) or small (1). Farlow et al. (1991) quantify this difference.
88. Serrations simple, denticles convex (0) or distal and often mesial edges of teeth with large, hooked denticles that point toward the tip of the crown (1).
89. Maxillary and dentary teeth constricted between root and crown (0) or root and crown confluent (1).
90. Dentary teeth evenly spaced (0) or anterior dentary teeth smaller, more numerous, and more closely appressed than those in middle of tooth row (1).
91. Dentaries lack distinct interdental plates (0) or 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, but in the absence of convincing evidence for this fusion we did not recognize this distinction.

Axial skeleton

92. Zygapophyses of trunk vertebrae abutting one another above neural canal, opposite hyposphenes meet to form lamina (0), or zygapohyses placed lateral to neural canal and separated by groove for interspinuous ligaments, hyposphenes separated (1).

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93. In cross section, premaxillary tooth crowns suboval to subcircular (0) or asymmetrical (D-shaped in cross section) with flat lingual surface (1).
94. Number of cervical vertebrae: 10 (0), or 12 or more (1).
95. Axial epipophyses absent or poorly developed, not extending past posterior rim of postzygopophyses (0) or large and posteriorly directed, extend beyond postzygapophyses (1).
96. Axial neural spine flared transversely (0) or compressed mediolaterally (1).
97. Epipophyses of cervical vertebrae placed distally on postzygapophyses, above postzygopophyseal facets (0) or placed proximally, proximal to postzygapophyseal facets (1).
98. Anterior cervical centra level with or shorter than posterior extent of neural arch (0), or centra extending beyond posterior limit of neural arch (1).
99. Carotid process on posterior cervical vertebrae absent (0) or present (1).
100. Anterior cervical centra subcircular or square in anterior view (0) or distinctly wider than high, kidney-shaped (1).
101. Cervical neural spines anteroposteriorly long (0) or short and centered on neural arch, giving arch an "X" shape in dorsal view (1).
102. Cervical centra with one pair of pneumatic openings (0) or with two pairs of pneumatic openings (1).
103. Cervical and anterior trunk vertebrae amphiplatyan (0) or opisthocoelous (1).
104. Anterior trunk vertebrae without prominent hypapophyses (0) or with large hypapophyses (1).
105. Parapophyses of posterior trunk vertebrae flush with neural arch (0) or distinctly projected on pedicels (1).
106. Hyposphene–hypantrum articulations in trunk vertebrae absent (0) or present (1).
107. Cervical vertebrae but not dorsal vertebrae pneumatic (0), or all presacral vertebrae pneumatic (1).
108. Transverse processes of anterior dorsal vertebrae long and thin (0) or short, wide, and only slightly inclined (1).
109. Neural spines of dorsal vertebrae not expanded distally (0) or expanded to form "spine table" (1).
110. Scars for interspinous ligaments terminate at apex of neural spine in dorsal vertebrae (0) or terminate below apex of neural spine (1).
111. Number of sacral vertebrae: 5 (0) or 6 (1), or 8 or more (2). Ordered.
112. Ventral surface of posterior sacral centra gently rounded, convex (0) or ventrally flattened, sometimes with shallow sulcus (1) or centrum strongly constricted transversely, ventral surface keeled (2). Note that in *Alvarezsaurus calvoi* it is only the fifth sacral that is keeled, unlike other alvarezsaurids (Novas 1997).
113. Pleurocoels absent on sacral vertebrae (0) or present on anterior sacrals only (1), or present on all sacrals (2). A pleurocoel may be present on the first sacral in *Alxasaurus elesitaiensis*, although this area is badly crushed (Russell and Dong 1993b). Ordered.
114. Last sacral centrum with flat posterior articulation surface (0) or convex articulation surface (1).
115. Sacral vertebrae with fused zygapophyses forming a sinuous ridge in dorsal view: absent (0) or present (1).
116. Caudal vertebrae with distinct transition point, from shorter centra with long transverse processes proximally to longer centra with small or no transverse processes distally (0), or vertebrae homogeneous in shape, without transition point (1).
117. Transition point in caudal series begins distal to the 10th caudal (0), or at or proximal to the 10th caudal vertebra (1).
118. Anterior caudal centra tall, oval in cross section (0) or with box-like centra in caudals I to V (1), or anterior caudal centra laterally compressed with ventral keel (2).
119. Neural spines of caudal vertebrae simple, undivided (0) or separated into anterior and posterior alae throughout much of caudal sequence (1).
120. Neural spines on distal caudals form a low ridge (0) or spine absent (1), or midline sulcus in center of neural arch (2).
121. Prezygapophyses of distal caudal vertebrae between one-third and whole centrum length (0) or with extremely long extensions of the prezygapophyses (up to 10 vertebral segments long in some taxa) (1), or strongly reduced as in *Archaeopteryx lithographica* (2).
122. More than 40 caudal vertebrae (0) or 25 to 40 caudal vertebrae (1), or no more than 25 caudal vertebrae (2). Ordered.
123. Proximal end of chevrons of proximal caudals short anteroposteriorly, shaft cylindrical (0) or proximal end elongate anteroposteriorly, flattened and plate-like (1).
124. Distal caudal chevrons are simple (0) or anteriorly bifurcate (1).
125. Shaft of cervical ribs slender and longer than vertebra to which they articulate (0) or broad and shorter than vertebra (1).

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126. Ossified uncinate processes absent (0) or present (1).
127. Ossified ventral rib segments absent (0) or present (1).
128. Lateral gastral segment shorter than medial one in each arch (0) or distal segment longer than proximal segment (1).
129. Ossified sternal plates separate in adults (0) or fused (1).
130. Sternum without distinct lateral xiphoid process posterior to costal margin (0) or with lateral xiphoid process (1).
131. Articular facet of coracoid on sternum (conditions may be determined by the articular facet on coracoid in taxa without ossified sternum): anterolateral or more lateral than anterior (0); almost anterior (1) (Xu et al. 1999).
132. Anterior edge of sternum grooved for reception of coracoids (0) or sternum without grooves (1).

Pectoral girdle

133. Hypocleidium on furcula absent (0) or present (1). The hypocleidium is a process extending from the ventral midline of the furcula, and is ligamentously attached to the sternum in extant birds.
134. Acromion margin of scapula continuous with blade (0) or anterior edge laterally everted (1).
135. Scapula longer than humerus (0) or humerus longer than scapula (1).
136. Anterior surface of coracoid ventral to glenoid fossa unexpanded (0) or anterior edge of coracoid expanded, forms triangular subglenoid fossa bounded laterally by coracoid tuber (1).
137. Scapula and coracoid separate (0) or fused into scapulacoracoid (1).
138. Coracoid in lateral view subcircular, with shallow ventral blade (0) or subquadrangular with extensive ventral blade (1), or shallow ventral blade with elongate posteroventral process (2).
139. Scapula and coracoid form a continuous arc in posterior and anterior views (0) or coracoid inflected medially, scapulocoracoid L-shaped in lateral view (1).
140. Glenoid fossa faces posteriorly or posterolaterally (0) or laterally (1).

Forelimb

141. 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 (3), or proximal end of humerus extremely broad, triangular in anterior view (4).
142. Anterior surface of deltopectoral crest smooth (0) or with distinct groove or ridge near lateral edge along distal end of crest (1).
143. Olecranon process weakly developed (0) or distinct and large (1).
144. Distal articular surface of ulna flat (0) or convex, semilunate surface (1).
145. Proximal surface of ulna a single continuous articular facet (0) or divided into two distinct fossae separated by a median ridge (1).
146. Lateral proximal carpal (ulnare?) quadrangular (0) or triangular in proximal view (1). 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.
147. Two distal carpals in contact with metacarpals, one covering the base of metacarpal I (and perhaps contacting metacarpal II), the other covering the base of metacarpal II (0), or a single distal carpal capping metacarpals I and II (1). 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.
148. Distal carpals not fused to metacarpals (0) or fused to metacarpals, forming carpometacarpus (1).
149. Semilunate distal carpal well developed, covering all of proximal ends of metacarpals I and II (0), or small, covering about half of base of metacarpals I and II (1), or covers bases of all metacarpals (2).
150. Metacarpal I half the length of metacarpal II (0) or less than half the length of metacarpal II (1), or subequal in length to metacarpal II (2).
151. Third manual digit present, phalanges present (0) or reduced to no more than metacarpal splint (1).
152. Manual unguals strongly curved, with large flexor tubercles (0), or weakly curved or straight with weak flexor tubercles displaced distally from articular end (1).
153. Unguals on all digits generally similar in size (0) or digit I bearing large ungual and unguals of other digits distinctly smaller (1).
154. Proximodorsal "lip" on some manual unguals—a transverse ridge immediately dorsal to the articu-

Appendix 1, continued.

lating surface—absent (0) or present (1). In *Velociraptor mongoliensis* and *Deinonychus antirrhopus* a lip is present, contrary to previous contentions.

Pelvic girdle

155. Ventral edge of anterior ala of ilium straight or gently curved (0), or ventral edge "hooked" anteriorly (1) or very strongly hooked (2). Ordered.
156. Preacetabular part of ilium roughly as long as postacetabular part of ilium (0) or preacetabular portion of ilium markedly longer (more than two-thirds of total ilium length) than postacetabular part (1).
157. Anterior end of ilium gently rounded or straight (0) or anterior end strongly curved (1) or pointed at anterodorsal corner (2). Ordered.
158. Supraacetabular crest on ilium as a separate process from antitrochanter, forms "hood" over femoral head present (0) reduced, not forming hood (1) or absent (2).
159. Tuber along dorsal edge of ilium, dorsal or slightly posterior to acetabulum absent (0) or present (1).
160. Postacetabular ala of ilium in lateral view squared (0) or acuminate (1).
161. Postacetabular blades of ilia in dorsal view parallel (0) or diverge posteriorly (1).
162. Brevis fossa shelf-like (0) or deeply concave with lateral overhang (1).
163. Antitrochanter posterior to acetabulum absent or poorly developed (0) or prominent (1).
164. Cuppedicus fossa formed as antiliac shelf anterior to acetabulum, extends posteriorly to above anterior end of acetabulum (0) or posterior end of fossa on anterior end of pubic peduncle, anterior to acetabulum (1).
165. Cuppedicus fossa deep, ventrally concave (0) or fossa shallow or flat, with no lateral overhang (1) or absent (2).
166. Posterior edge of ischium straight (0) or with median posterior process (1).
167. Ischium straight (0) or ventrodistally curved anteriorly (1) or twisted at midshaft and with flexure of obturator process toward midline so that distal end is horizontal (2) or with laterally concave curvature in anterior view (3).
168. Obturator process of ischium absent (0) or proximal in position (1) or located near middle of ischiadic shaft (2), or located at distal end of ischium (3).
169. Obturator process does not contact pubis (0) or contacts pubis (1).
170. Obturator notch present (0) or obturator foramen completely enclosed (1) or notch or foramen absent (2).
171. Semicircular scar on posterior part of the proximal end of the ischium, absent (0) or present (1).
172. Tubercle on anterior edge of ischium absent (0) or present (1).
173. Ischium more than two-thirds (0), or two-thirds or less of pubis length (1).
174. Distal ends of ischia form symphysis (0), or approach one another but do not form symphysis (1), or widely separated (2). Ordered.
175. Ischial "foot" (expanded distal end) present (0) or absent (1).
176. Pubis propubic (0) or pubis vertical (1), or pubis posteriorly oriented (opisthopubic) (2). 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. Ordered.
177. Pubic boot projects anteriorly and posteriorly (0) or with little or no anterior process (1), or no anteroposterior projections (2).
178. Shelf on pubic shaft proximal to symphysis ("pubic apron") extends medially from middle of cylindrical pubic shaft (0) or shelf extends medially from anterior edge of anteroposteriorly flattened shaft (1).
179. Pubic shaft straight (0) or distal end curves anteriorly, anterior surface of shaft concave (1) .
180. Pubic apron about half of pubic shaft length (0) or less than one-third of shaft length (1).

Hind limb

181. Femoral head without fovea capitalis (for attachment of capital ligament) (0) or circular fovea present in center of medial surface of head (1).
182. Lesser trochanter separated from greater trochanter by deep cleft (0) or trochanters separated by small groove (1) or completely fused (or absent) to form crista trochanteris (2).
183. Lesser trochanter of femur alariform (0) or cylindrical in cross section (1).
184. Posterior trochanter absent or represented only by rugose area (0) or posterior trochanter distinctly raised from shaft, mound-like (1). Cited by Gauthier (1986) as synapomorphy of Coelurosauria (his character 64), but he termed it the greater trochanter, which he equated with the posterior trochanter. Ostrom (1969a, 1990) identifies the posterior and greater trochanter as separate structures, and we follow his terminology.
185. Fourth trochanter on femur present (0) or absent (1).
186. Accessory trochanteric crest distal to lesser trochanter

Appendix 1, continued.

absent (0) or present (1). This character was identified as an autapomorphy of *Microvenator celer* (Makovicky and Sues 1998), but it is more widespread.

187. Anterior surface of femur proximal to medial distal condyle without longitudinal crest (0) or crest present extending proximally from medial condyle on anterior surface of shaft (1).
188. Popliteal fossa on distal end of femur open distally (0) or closed off distally by contact of distal condyles (1).
189. Fibula reaches proximal tarsals (0) or short, tapering distally, and not in contact with proximal tarsals (1).
190. Medial surface of proximal end of fibula concave along long axis (0) or flat (1).
191. Deep oval fossa on medial surface of fibula near proximal end absent (0) or present (1).
192. Distal end of tibia and astragalus without distinct condyles (0) or with distinct condyles separated by prominent tendinal groove on anterior surface (1).
193. Medial cnemial crest absent (0) or present on proximal end of tibia (1).
194. Ascending process of the astragalus tall and broad, covering most of anterior surface of distal end of tibia (0), or process short and slender, covering only lateral half of anterior surface of tibia (1), or ascending process tall with medial notch that restricts it to lateral side of anterior face of distal tibia (2).
195. Ascending process of astragalus confluent with condylar portion (0) or separated by transverse groove or fossa across base (1).
196. Astragalus and calcaneum separate from tibia (0) or fused to each other and to the tibia in late ontogeny (1).
197. Distal tarsals separate, not fused to metatarsals (0) or form metatarsal cap with intercondylar prominence that fuses to metatarsal early in postnatal ontogeny (1).
198. Metatarsals not co-ossified (0) or co-ossification of metatarsals begins proximally (1) or distally (2).
199. Distal end of metatarsal II smooth, not ginglymoid (0) or with well-developed ginglymus (1).
200. Distal end of metatarsal III smooth, not ginglymoid (0), or with well-developed ginglymus (1).
201. Proximal surface of metatarsal IV subequal to II in size, proximal end of metatarsal III visible between metatarsals II and IV in anterior view (0), or metatarsal III pinched between metatarsals II and IV, the latter two contacting one another proximally in front of III (1), or metatarsal III does not reach proximal end of metatarsus (2). Ordered.
202. Shaft of metatarsal IV round or thicker dorsoventrally than wide in cross section (0) or shaft of metatarsal IV mediolaterally widened and flat in cross section (1).
203. Metatarsal I articulates in the middle of the medial surface of metatarsal II (0), or metatarsal I attaches to posterior surface of distal quarter of metatarsal II (1), or metatarsal I articulates to medial surface of metatarsal II near its proximal end (2), or metatarsal I absent (3).
204. Metatarsal I attenuates proximally, without proximal articulating surface (0) or proximal end of metatarsal I similar to that of metatarsals II, III and IV (1).
205. Ungual and penultimate phalanx of pedal digit II similar to those of III (0) or penultimate phalanx highly modified for extreme hyperextension, ungual more strongly curved and about 50% larger than that of III (1).

Appendix 2: Unambiguous synapomorphies for clades

The first number refers to the character list; second and third numbers refer to the direction of state change. Species belonging to monospecific genera are referenced by the generic name alone.

Mononykinae:
- char 106: 1 → 0
- char 149: 0 → 2
- char 176: 1 → 2
- char 182: 1 → 2
- char 188: 0 → 1
- char 192: 0 → 1
- char 194: 0 → 1
- char 195: 0 → 2
- char 205: 0 → 2

Patagonykus + Mononykinae:
- char 196: 0 → 1

Alvarezsauridae:
- char 112: 1 → 2
- char 114: 0 → 1

Archaeopteryx + *Confuciusornis*:
- char 197: 0 → 1
- char 198: 0 → 1

Avialae:
- char 122: 1 → 2
- char 135: 0 → 1
- char 180: 0 → 1

Struthiomimus + *Gallimimus*:
- char 201: 0 → 1

Saurornithoides junior + *S. mongoliensis:*
- char 6: 1 → 0

Troodon formosus + (*Saurornithoides junior* + *S. mongoliensis*):
- char 67: 0 → 1

Troodontidae:
- char 73: 0 → 1
- char 90: 0 → 1

Tyrannosauridae:
- char 9: 1 → 0
- char 48: 0 → 2
- char 49: 0 → 1
- char 50: 0 → 1
- char 56: 0 → 1
- char 79: 0 → 1
- char 107: 0 → 1
- char 113: 0 → 1
- char 151: 0 → 1
- char 158: 0 → 1
- char 170: 0 → 1
- char 201: 0 → 1

Therizinosauroidea:
- char 71: 0 → 1
- char 141: 1 → 0

Ornithomimosauria:
- char 26: 0 → 2
- char 69: 1 → 0

Dromaeosauridae + Avialae:
- char 136: 0 → 1
- char 166: 0 → 1
- char 157: 0 → 12

Oviraptoridae:
- char 3: 0 → 1
- char 133: 0 → 1
- char 137: 0 → 1

Chirostenotes + *Avimimus*
- char 173: 0 → 1
- char 201: 0 → 1

Caudipteryx + Oviraptoridae:
- char 182: 0 → 1

Microvenator + (*Caudipteryx* + Oviraptoridae)
- char 107: 0 → 1
- char 179: 0 → 1
- char 184: 1 → 0

Oviraptorosauria:
- char 30: 0 → 1
- char 32: 0 → 1
- char 60: 0 → 1
- char 68: 0 → 1
- char 72: 0 → 2
- char 80: 0 → 1
- char 81: 0 → 1
- char 84: 0 → 1

Therizinosauroidea + Oviraptorosauria:
- char 21: 0 → 1
- char 29: 0 → 1
- char 59: 1 → 0
- char 67: 0 → 2
- char 70: 0 → 1
- char 76: 1 → 0
- char 82: 0 → 1
- char 123: 1 → 0

Troodontidae + (Therizinosauroidea + Oviraptorosauria):
- char 5: 0 → 1
- char 7: 1 → 0
- char 22: 0 → 1
- char 69: 1 → 0
- char 86: 0 → 1
- char 87: 1 → 0
- char 154: 0 → 1

Dromaeosauridae, Avialae + (Troodontidae + (Therizinosauroidia + Oviraptorosauria)):
- char 127: 0 → 1
- char 130: 0 → 1
- char 131: 0 → 1
- char 138: 2 → 1
- char 140: 0 → 1
- char 184: 0 → 1

Alvarezsauridae + ((Dromaeosauridae, Avialae) + (Troodontidae + (Therizinosauroidea + Oviraptorosauria))):
- char 26: 0 → 1
- char 42: 1 → 2
- char 47: 0 → 1
- char 49: 0 → 1
- char 155: 1 → 0
- char 162: 1 → 0
- char 170: 0 → 1
- char 171: 0 → 1

Maniraptora:
- char 42: 0 → 1
- char 55: 0 → 1
- char 59: 0 → 1
- char 92: 0 → 1
- char 104: 0 → 1
- char 120: 0 → 1
- char 160: 0 → 1
- char 164: 0 → 1
- char 176: 0 → 1

Coelurosauria:
- char 6: 0 → 1
- char 8: 1 → 0
- char 15: 1 → 0
- char 16: 1 → 0
- char 17: 1 → 0
- char 23: 0 → 1
- char 39: 1 → 0
- char 40: 1 → 0
- char 66: 0 → 1
- char 78: 0 → 1/2
- char 91: 1 → 0
- char 95: 1 → 0
- char 96: 0 → 1
- char 97: 0 → 1
- char 98: 0 → 1
- char 100: 0 → 1
- char 110: 0 → 1
- char 112: 0 → 1
- char 123: 0 → 1
- char 125: 0 → 1
- char 138: 0 → 2

Tyrannosauridae + Coelurosauria:
- char 31: 0 → 1
- char 93: 0 → 1
- char 103: 1 → 0
- char 194: 1 → 0
- char 195: 0 → 1

Appendix 3: Data matrix (version 99.1)

	10	20	30	40	50	60	70
Allosaurus fragilis	?101000110	000?111000	00?0010000	0000111011	0010-?0000	0000000100	0100000010
Sinraptor dongi	?00100?110	?00?11?0?0	0000000000	0000001011	0010-000?0	0000000000	0100000010
Ingenia yanshini	??1????010	??????????	????????11	??????????	??????????	??????????	??????21-1
Oviraptor mongoliensis	?11????010	1?0???????	??????1011	?1?11?0001	0??00????0	00?0??????	00???121-1
Oviraptor philoceratops	?11101?010	1????1???0	1????01???	?1011???0?	??1?0??11?	???01??0??	?0?1?121-1
Conchoraptor gracilis	?11????010	1?????????	?????01011	?1?11?000?	?210001110	0?00?????1	?0????21-1
Oviraptorid IGM 100/42	?0110?0010	10110?0000	1-22101011	11011?0001	0210001110	0000110001	00010121-1
Chirostenotes pergracilis	?1?01-0???	?11?00?0?0	11????????	11????????	??????????	??????0101	0?????21-1
Dromaeosaurus albertensis	?????010?0	0001001000	00001????0	?0?01110??	??1111????	1?0010?100	1100??0010
Deinonychus antirrhopus	?001011010	0?1???????	????1?1000	?000111000	11????1??0	1?????0?00	?110010010
Velociraptor mongoliensis	?001011010	0011111000	0020121000	1000111000	12111?110?	1000100000	1110010010
Mononykus olecranus	??????????	???0??0???	??112?????	??????????	??????????	????????10	0?????????
Shuvuuia deserti	?00?00?010	01000?0000	0011210100	?0-111-110	0210001010	0110100010	?-?11?0011
Patagonykus puertai	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Alvarezsaurus calvoi	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Ornitholestes hermanni	?101011010	0??????00?	001??01?00	?0001?1000	01?0??0100	000010?010	11????0010
Microvenator celer	??????????	??????????	??????????	??????????	??????????	??????????	??????2??1
Archaeopteryx lithographica	1101011010	?1?00?0?00	0?11211000	???111?000	12100??10?	00000???10	01111?0010
Avimimus portentosus	???????010	??0?00?101	1?0?????11	???1?-?1??	???00??11-	0??0100011	0?????21??
Caudipteryx zoui	010100?010	??????????	?????00?11	??001?10??	?210001???	?000??????	??????21-1
Unenlagia comahuensis	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Confuciusornis sanctus	10000??010	0?????????	?????10-00	?0001???0?	?2??0?1?1?	0?10???01?	??????1000
Rahonavis ostromi	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Struthiomimus altus	?001011011	?00?0?01??	0?10121100	101-110000	1000000000	00010???00	01?0?10000
Gallimimus bullatus	?000010011	000?000111	0110121110	101-111020	1000000000	0001000000	01?0010000
Garudimimus brevipes	?001101010	0?0?????11	01???21?10	1000??000?	10?00?00?0	00??????00	01???1?00?
Pelecanimimus polyodon	?00??1001?	????????1?	?????21??0	??????????	?0??0?????	??????????	???????000
Harpymimus okladnikovi	???????0??	??????????	?????2???0	??????????	??????????	??????????	????????01
Troodon formosus	??0111????	?1-1000211	010001??0?	?0??????20	2200001210	0?0??11110	0???0?1?00
Saurornithoides mongoliensis	?00110001?	?1????0?11	01??010100	1?????????	2?????????	??????????	?1?0011000
Byronosaurus jaffei	?101?1????	?1?00?0?11	0111010100	10??????20	220???????	????????10	0?????0000
Saurornithoides junior	?001000010	?1-?000211	010?010?00	??00????20	22000?121?	0?????1110	0?????1000
Sinornithoides youngi	?001???0?0	?1????????	?????1??00	??????00??	?2????????	?10???????	??????0?00
Segnosaurus galbinensis	??????????	??????????	??????????	??????????	??????????	??????????	????????01
Erlikosaurus andrewsi	?1001-?010	1?-?00020-	1-??110010	10001?1000	0010001010	00?0??0000	0??1112001
Alxasaurus elesitaiensis	??????????	??????????	??????????	??????????	??????????	??????????	??????2001
Tyrannosaurus rex	?001001100	001?111100	0000200000	1000000011	0000100211	0000010100	01?0000010
Albertosaurus libratus	?0010?1100	00??1??00?	?????00000	1000000011	0000-?0211	00?0010100	01????0010
Adasaurus mongoliensis	??????????	??????????	??????????	??????????	??????????	??????????	??????????
Utahraptor ostrommaysorum	??????????	??????????	??????1??0	????????00	1?????????	??????????	??????????
Saurornitholestes langstoni	??????????	??????????	??????????	??????????	???111????	??????????	?11???0???
Achillobator giganticus	???10?1???	??????????	??????????	?0????????	??????????	??????????	??????????
IGM 100/1015	?001001010	0011111000	0020121000	10001?1000	1211?11100	1000?0?001	01?0??0010
Sinornithosaurus milleni	?00101101?	????????0?	?????????0	??????1000	1111001?1?	??0?10????	??????0?10

Appendix 3, continued.

	80	90	100	110	120	130	140
Allosaurus fragilis	0000010000	0000001010	1000100000	0010010000	0000000010	00000?01??	??00000000
Sinraptor dongi	0000?10?00	0000001010	1000100000	0010010000	00000000??	????????2?	00?00?0??0
Ingenia yanshini	0201000?01	11?1------	-?-???????	??????????	1??0?1-???	2?00???001	11100011??
Oviraptor mongoliensis	?201000??1	11-1------	-?-???????	??????????	???0??????	210???????	??1?0?1???
Oviraptor philoceratops	0201?00?01	?1-1------	-?-???????	??????????	???0??????	??????????	1?1???1???
Conchoraptor gracilis	02010?0?01	11-1------	-?-???????	??010?1?01	1110???1??	???0??1???	?110001100
Oviraptorid IGM 100/42	0201000101	11-1------	-1-1011101	1001011100	1?20?1-?00	2100111?01	1110001101
Chirostenotes pergracilis	0200000?01	???1------	-1-???????	1101?1????	112????0??	??????????	??????01?1
Dromaeosaurus albertensis	0000111110	00?0001010	0?1???????	??????????	??????????	??????????	??????????
Deinonychus antirrhopus	0?00111?10	00?0101010	010?110001	100?111011	0/1??0?01101	1?111?????	1??1010111
Velociraptor mongoliensis	00001111?0	0010101010	010011?001	1001111011	1100101101	1111111001	1101011111
Mononykus olecranus	??????????	????2?--0?	?1??????1?	1?1110001?	???1?0?2??	????1???20	00?0000200
Shuvuuia deserti	0100000210	0?1022--00	01??011111	101110?0??	1201?01201	2210100?20	00?0000200
Patagonykus puertai	??????????	??????????	?1????????	????11????	???1?0?2??	??????????	?????00200
Alvarezsaurus calvoi	??????????	??????????	??????????	100???????	?2?1?0?2?1	2?????????	???0??0?00
Ornitholestes hermanni	00000?0?00	0010 0/1 01010	011?????01	1?01010000	??00?0?001	0??1??????	????0?????
Microvenator celer	020???????	??????????	?1??011?0?	1100011100	??0??1-100	2?????????	???0?0?000
Archaeopteryx lithographica	0000000??0	000020--00	1?00?1?1??	?00?0?0?0?	0??0?01101	2211000?1?	1?01111111
Avimimus portentosus	??00?0??01	11-?------	-?-?011010	1101010?00	?100??????	??????????	????0?????
Caudipteryx zoui	020???????	?0?1------	-?00????0?	?00???????	0??0?1-???	?20?????0?	??0?0?0???
Unenlagia comahuensis	??????????	??????????	?1????????	????111?11	???0??????	??????????	???10?0??1
Confuciusornis sanctus	0100?10?00	01-1?-????	?1?0??????	????10??0?	2??0??????	?2?-111?21	100?1-1-11
Rahonavis ostromi	??????????	??????????	?1????????	??01?11???	101??01111	2211??????	????1????1
Struthiomimus altus	0100010200	01-1------	-0-001?101	1000010000	1100000000	01101001??	???0011200
Gallimimus bullatus	0000000200	01-1------	-0-0011101	1000010000	1100?00000	0110100???	???0010200
Garudimimus brevipes	????0?02?0	?1-1------	-?-???????	??????0???	1?0???????	??????????	??????????
Pelecanimimus polyodon	0?00??????	?00022—00	0?1???????	??????????	??????????	????????0?	00?????2??
Harpymimus okladnikovi	0??00?????	????20--1-	??????????	??????????	??????????	??????????	??????????
Troodon formosus	0?1???????	???0110101	010???1111	1001010111	1100?0?102	0??11?????	?????????1
Saurornithoides mongoliensis	0?10??1???	?000110101	??????????	1???0?0???	?100???1??	??????????	??????????
Byronosaurus jaffei	001??11???	?00021--01	?10?0?????	??01010???	?????0??02	??????????	??????????
Saurornithoides junior	0?1???1???	?000110101	0?0???????	??????????	1100?0?102	0?1???????	??????????
Sinornithoides youngi	0?10??????	?000110?01	???????11?	?001??????	???0?011?1	0111101???	1?-000?1?1
Segnosaurus galbinensis	1??0000?00	0???010000	1?????????	??????????	???0??????	??????????	??????11??
Erlikosaurus andrewsi	1000000200	01-0010000	1?-???????	??????????	??????????	??????????	??????????
Alxasaurus elesitaiensis	1?0???????	?????10?00	10????????	??0?010000	01?0?01??0	2?0?1?????	????0?????
Tyrannosaurus rex	0000110010	0000001010	1010100000	-000011000	0010000?0	01000??1??	???0000000
Albertosaurus libratus	0000?10010	0000001010	1010100000	-0/100011000	0010000000	010000?100	1100000000
Adasaurus mongoliensis	??????????	?0?0??????	??????????	??????????	??????????	??????????	??????????
Utahraptor ostrommaysorum	??????????	?0????101?	??1???????	??????????	?????0??01	1?????????	??????????
Saurornitholestes langstoni	??????????	????10101?	010?110001	1001111011	011010?101	1?111?????	??????????
Achillobator giganticus	??????????	???000101?	?1????0?01	100?1110??	?????0??01	1?11??????	?????101??
IGM 100/1015	0000?11110	0010101010	0?0????0??	1?????????	??????????	??????????	??????????
Sinornithosaurus milleni	0000??1???	?01010??10	0?????????	1??1??????	0??0?0?1??	1???????01	11?1010111

Appendix 3, continued.

	150	160	170	180	190	200	210
Allosaurus fragilis	0000000?0	0000100000	0100000100	000000000?	0000011000	0001000000	00000
Sinraptor dongi	??0???????	0000100000	?10??00100	0000000?00	000000?000	0001000000	00000
Ingenia yanshini	0000??1000	0001002?1	?????03201	0001110?11	01101?0000	?00010?000	00000
Oviraptor mongoliensis	0?0???10??	0001100??1	???11?????	????????1?	???????0??	??0??0?0??	?????
Oviraptor philoceratops	?00???1?0?	?00?00???1	?0????????	??????????	???????0??	??0????0??	?????
Conchoraptor gracilis	010???????	?001100201	001-10???1	00???1001?	?11010?0??	??0??0?000	0??0?
Oviraptorid IGM 100/42	0100?11001	0001000201	100??03201	00??110111	?210100000	0000?00000	00000
Chirostenotes pergracilis	??????????	00?1?0020?	?0?1?03201	00111?01??	?0????????	?00?100⁰/₁00	10000
Dromaeosaurus albertensis	??????????	??????????	??????????	??????????	??????????	??????????	????1
Deinonychus antirrhopus	0100111001	0001002211	101110220?	01111?0100	?111100000	0000100011	01001
Velociraptor mongoliensis	0100111001	0001002211	1011102201	0111121100	1111⁰/₁00000	0000101011	01001
Mononykus olecranus	30110-1122	0110???1??	??1??000-1	?????2??0-	?210100111	0112110000	20000
Shuvuuia deserti	3011?-1122	011000?10-	-21-2000-1	0002122-0-	?210100111	0112110000	20000
Patagonykus puertai	30110?110?	?110??????	??1??????1	?????10?00	?11?1?00??	?00011?0??	0????
Alvarezsaurus calvoi	????????0?	?????001?1	-0??2?????	??????????	?1?00???0?	?0??100000	0???0
Ornitholestes hermanni	1?00??????	????1000?1	?1?1?01100	000011??0?	???????0??	??????00?0	0????
Microvenator celer	11000?????	?00100???	?0010?????	??????0110	?0101100?0	000010????	???0?
Archaeopteryx lithographica	1000?11001	0000011211	1001?10301	0012-11?01	?111100000	?000?01100	0?100
Avimimus portentosus	100???????	????00?2?1	101??03201	0010?10?0?	000100?0??	?000111100	1???0
Caudipteryx zoui	??0???1001	000?100??1	?????0?201	????1???10	?11?????0?	???01000??	0?00?
Unenlagia comahuensis	01????????	????012211	?0?111?201	0?1??11100	?1?01??0??	??????????	?????
Confuciusornis sanctus	400?111111	0000011211	???-?1?0?1	?011122?01	12??10??11	??12011101	0?100
Rahonavis ostromi	??011?????	??0?011211	?0?-?103?1	0012?1??01	?21??0000?	?0??100011	01?01
Struthiomimus altus	20000000-2	0100100000	0110001100	1000000000	0000011000	1000100000	103-0
Gallimimus bullatus	200000?0-2	0100100000	0110001100	1000000100	0000011000	1000100000	103-0
Garudimimus brevipes	??????????	??????0??0	??0???????	??????????	???????0??	??????0000	0??00
Pelecanimimus polyodon	??00??00-2	010???????	??????????	??????????	??????????	??????????	?????
Harpymimus okladnikovi	2?00?00000	010?10???0	??????????	??????????	??????????	??????0000	0???0
Troodon formosus	010????0?0	00010?????	?????032?1	00?1100?0?	01111000??	?000100000	10??1
Saurornithoides mongoliensis	??????????	??????????	?????03201	00?01⁰/₁?10?	?11110????	???????0??	100?1
Byronosaurus jaffei	??????????	??????????	??????????	??????????	??1????0?0	??0???????	????1
Saurornithoides junior	??????????	??????????	??????????	??????????	??????????	???01?????	?????
Sinornithoides youngi	1?0???1001	000????2?1	?01??0?30?	???110??00	??1110????	?0?????000	?0001
Segnosaurus galbinensis	00????????	010?200201	?000?10211	?00?120?0?	???????00?	?0?00??000	0?21?
Erlikosaurus andrewsi	0?????????	??????????	??????????	??????????	??????????	??????0?00	????0
Alxasaurus elesitaiensis	0000?100-0	0001200201	?0?1100211	??0212????	?01????00?	???????000	00210
Tyrannosaurus rex	10000??0-?	1000100100	0100000101	1001100000	?010010000	?000100000	10000
Albertosaurus libratus	10000000-0	1000100100	0100000101	1000100000	0010000000	1000100000	10000
Adasaurus mongoliensis	??????????	????1?2211	1?11?0?201	??1?121?0?	??????????	??????????	????1
Utahraptor ostrommaysorum	??????????	?0?0??????	??????????	??????????	??????????	??00?0????	?????
Saurornitholestes langstoni	??????????	0001??????	??????????	??????????	??????????	??????????	?????
Achillobator giganticus	??????????	00??1022?1	?111100101	?001110?00	?21110?0??	??00?000?1	0???1
IGM 100/1015	??????????	??????????	??????????	??????????	??????????	??????????	?????
Sinornithosaurus milleni	0?0????0?1	000?00?2?1	101?11?3?1	?011111?0?	???1??????	???110001?	1?001