1. Phylogenetic Nomenclature

We followed Sereno et al. (2004)[1] and Ezcurra (2006[2]) with respect to the definitions of several higher-level theropod taxa used in this paper:

Averostra, the least inclusive clade including *Ceratosaurus nasicornis* and Neornithes

Tetanurae, the most inclusive clade including Neornithes but not *Ceratosaurus nasicornis*

Aves, the least inclusive clade including Neornithes and *Archaeopteryx lithographica*

Coelophysoidea, the most inclusive clade including *Coelophysis bauri* but not Neornithes.

Ceratosauria, the most inclusive clade including *Ceratosaurus nasicornis* but not Neornithes.

Abelisauroidea, the least inclusive clade including *Carnotaurus sastrei* and *Noasaurus leali*.

Noasauridae, the most inclusive clade including *Noasaurus leali* but not *Carnotaurus sastrei*.

Abelisauridae, the most inclusive clade including *Carnotaurus sastrei* but not *Noasaurus leali*.

2. Ontogenetic stages of the *Limusaurus inextricabilis* holotype and referred specimens

The *Limusaurus inextricabilis* holotype is estimated to be 170 cm in total body length based upon the length of the nearly complete skeleton and an estimate for the length of the missing distal caudals. All observed cranial elements except the left and right parietals are unfused. All observable sutures between the centra and neural arches are closed. The scapula and coracoid are fused to each other, but the suture is visible. The pelvic elements are not fused to each other. The astragalus and calcaneum are fused to each other, but not to the tibia. The distal tarsals remain separate. The referred specimen IVPP V 15924 is 15% larger than the holotype (based on tibiotarsus length). It is similar to the holotype in the extent of skeletal fusion except that the astragalus-calcaneum complex is fused to the tibia. As a whole, the evidence from osteological fusion suggests that neither specimen is a juvenile. The other referred specimen IVPP V16134 is probably at the same ontogenetic stage as the *Limusaurus inextricabilis* holotype, given that they are about the same size and display the same extent of skeletal fusion.

We also estimated the ontogenetic stage of IVPP V 15924 by examining a thin-section from the mid-shaft of the fibula. The bone (photographed with polarized microscopy) is heavily infiltrated with fungus and this led to some destruction of the microstructure (black blotches and root-like patterning are visible). Even so, the primary and secondary microstructure including growth lines is present in sufficient detail to allow histological characterizations and determination of the individual’s age. The inner half of the cortex is mostly composed of dense haversian bone (HC = round haversian canals in figure 1c). In other words, the primary bone has been heavily remodelled. This is common in dinosaurs as well as in extant mammals and birds[3]. There are multiple layers of endosteal bone (EB in figure 1c) lining the medullary cavity. Coupled with the dense haversian structure, this points to the individual’s being of advanced age, rather than a juvenile[4]. The primary bone that is present in places shows that during the majority of development a longitudinally vascularized, fibro-lamellar bone type predominated. This is common in small dinosaurs[3, 5]. Four definitive lines of arrested growth (aka: growth lines; white vertical arrows) are present. No more than one line was originally present where the medullary cavity now exists. This places the age of the animal at 5 years, meaning that it died in its sixth year of life. This is consistent with subadult age in a small dinosaur. Note that the three outermost growth lines locally expand into layers of lamellar bone, as is common in theropod dinosaurs. The outermost zones (areas of bone between the growth lines) are approximately 1/2 to 1/3rd the radius of the earlier zones. This indicates that the animal's growth was beginning to slow at the time of its demise, but that growth was still incomplete. Together with the dense haversian bone, extensive and multiple endosteal bone deposition events, and the fact that a larger individual is known from the same site, this finding points to the conclusion that the individual was a young adult - probably between the exponential and stationary phases of development.

3. Morphological comparisons

Limusaurus inextricabilis has the following ceratosaurian features[6-8]: skull relatively tall, antorbital fenestra relatively small, premaxilla with short maxillary process and long and robust nasal process, maxilla contributing to ventral border of external naris, nasal with anterolateral margin slightly convex laterally and posterolateral margin contributing to antorbital cavity, lacrimal with anterior process short and slender relative to ventral process, external mandibular fenestra large, dentary short compared to postdentary elements, angular positioned significantly anterior to posterior end of mandible (Fig. S1a), proximal head of humerus bulbous, deltopectoral crest long and obliquely oriented, ossified carpals absent (Fig. S1c), distal end of pubis terminating in a large, caudally expanded foot, ischial antitrochanter large (Fig. S1d), anterior surface of distal femur with shallow extensor groove, and pedal unguals with two lateral grooves.

Among ceratosaurs, *Limusaurus inextricabilis* shares some derived similarities with most other ceratosaurs except *Elaphrosaurus*[6]: post-axial cervical neural arches pneumatic, dorsal vertebrae with parapophyses on laterally projecting stalks, humerus non-twisted, medial epicondyle of femur flange-like, cnemial crest of tibia long anteroposteriorly, fibular M. iliofibularis tubercle large, calcaneum with large tibial facet, and main body of astragalus anterior to tibia.

Limusaurus lacks the following derived features that are present in *Ceratosaurus* and more derived ceratosaurs[6]: premaxilla dorsoventrally taller than anteroposteriorly long below external naris, nasals fused, frontals and parietals fused to each other and fused across midline, infratemporal fenestra large, quadrate and quadratojugal fused (Fig. S1a), pleurocoel present at cranial end of axis, pneumatic foramen or foramina in the axial neural arch, cranial margin of scapulocoracoid smoothly curved and uninterrupted by a notch at the scapulocoracoid contact (Fig. S1b), distal humeral condyles flattened, and proximal end of metacarpal I loosely appressed to metacarpal II. But *Limusaurus* appears to be more derived than Ceratosaurus in some features: proportionally shorter forelimbs, shorter forearms, and shorter manus (forelimb less than one-fifth of hind limb length, metacarpus less than one-third of forearm length), long coracoidal posterior process, prominent coracoidal tubercle, exceptionally high acromion process sharply deflected from unusually broad and distally unexpanded scapular blade, prominent furrow posterior to scapulocoracoid suture on lateral surface of scapula (Fig. S1b), and laterally inset pubic boot. Interestingly, in some phylogenetic analyses[9, 10] ceratosaurs represent a paraphyletic group and *Ceratosaurus* is found to be more closely related to tetanurans than to other ceratosaurs.

Limusaurus shares some similarities with noasaurids, including a suite of maxillary features, cervical neural spines positioned relatively anteriorly on corresponding centra (though not as anteriorly positioned as in noasaurids), and metatarsal II very slender for most of its length (also in *Elaphrosaurus*). Among noasaurids, *Limusaurus* is similar to *Masiakasaurus*[11] in the following characters: down-turned anterior end of dentary with convex buccal margin (Fig. S1a), manual unguals with two vascular grooves on each side, proximal half of femur sub-triangular in cross section, and metatarsal IV with transversely very narrow distal end compared to those of metatarsals II and III (also in *Deltadromeus*)[12,1]

Limusaurus and *Elaphrosaurus* are similar to each other in many features, most of which are plesiomorphic features also seen in coelophysids[6, 8]: cervical vertebrae significantly elongate (also present in coelophysoids), small, medially inclined ilium with ventral margins of both preacetabular and postacetabular blades laterally flared to form shelves, brevis fossa extensively laterally exposed, and a blunt, medially curved posteroventral process (Fig. S1d), and hind limbs elongate. Furthermore, *Limusaurus* is similar to coelophysids in the following features: prominent rim on external antorbital fenestra, external naris proportionally large and posteriorly extended, lacrimal ventral process with strongly posteriorly expanded distal end, angular forming nearly entire ventral border of external mandibular fenestra, axial parapophysis reduced, axial diapophysis absent, and ischium terminating distally in a knoblike swelling. It is worth noting that some of these features are also seen in noasaurids.

In addition, *Limusaurus* shares many derived similarities with tetanurans[13]. These include external naris large and posteriorly located, scapular acromial process prominent, scapulocoracoid notched between acromial process and coracoid, ventral coracoid process well-developed, fibular condyle strongly offset from tibial cnemial crest, distal end of tibia expanded to contact calcaneum, fibula closely appressed to tibia along entire length of the main shaft, and pedal digit I distally located.

The distribution of morphological characters during the early divergent period of theropod dinosaur evolution is fairly complex[14, 15]. This is further demonstrated by the anatomy of *Limusaurus*, which has a combination of the primitive and derived characters that are present in three major theropod groups. Much of the uncertainty concerning character evolution close to the base of the theropod tree is caused by a large amount of missing data in early theropods, particularly ceratosaurs and basal tetanurans. The prevalence of homoplastic evolution also helps to explain the complex pattern. A comprehensive analysis including more taxa and characters is needed to reconstruct the relationships among basal theropods and better understand the early evolution of theropod dinosaurs.

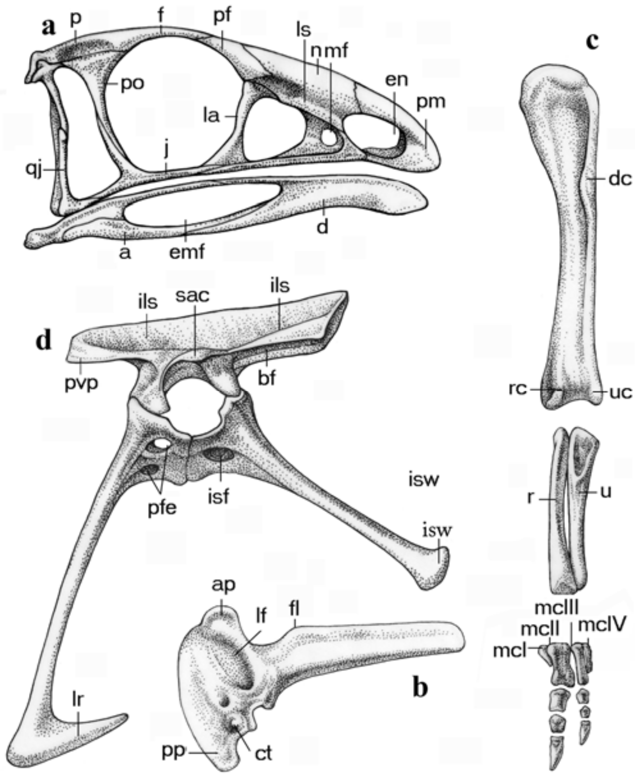

Figure S1. *Limusaurus inextricabilis* selected elements. **a**, Skull in lateral view; **b**, Left scapulocoracoid in lateral view; **c**, Left manus in dorsal view; **d**, Pelvis in lateral view. Abbreviations: a, angular; ap, acromion process; bf, brevis fossa; ct, coracoid tubercle; d, dentary; dc, deltopectoral crest; emf, external mandibular fenestra; en, external naris; f, frontal; fl, flange; lf, longitudinal furrow; ils, lateral shelf on ilium; ?isf, ischial foramen; lr, lateral ridge; ls, lateral shelf; mcI-IV, metacarpals I-IV; mf, maxillary fenestra; n, nasal; p, parietal; pf, prefrontal; pfe, pubic fenestra; pm, premaxilla; po, postorbital; pp, posterior process; qj, quadratojugal; r, radius; rc, radial condyle; sac, supraacetabular process; u, ulna; uc, ulnar condyle.

4. The manus in *Limusaurus inextricabilis* and other non-avian theropods.

The manus of *Limusaurus inextricabilis* is not preserved completely in any specimen, but the three specimens reported here allow a nearly complete reconstruction. Digit I, comprising only a greatly reduced metacarpal, is preserved in articulation in IVPP V16134 (Fig. S2) and in a disarticulated condition in IVPP V12594. Digit II is completely preserved in articulation in the holotype and disarticulated in V12594, and comprises a robust metacarpal and three phalanges. The morphology of metacarpal II varies between the two specimens: in the holotype the distal end is more strongly asymmetric and in V12594 there is a well developed flat surface, dorsodistally bordered by a small flange, in proximolateral contact with metacarpal III. Digit III is incompletely preserved in the holotype, retaining only the metacarpal, part of the penultimate phalanx, and the ungual phalanx, and in V12594 it includes the disarticulated metacarpal and three phalanges, the distal two in articulation. The articular surfaces on the distal surface of phalanx I and the proximal surface of the penultimate phalanx closely match, indicating that an unpreserved intermediate phalange was absent. Digit III therefore includes a metacarpal slightly longer than metacarpal II and more gracile, and three phalanges, of which the ungual phalanx is rotated 90 degrees medially and the penultimate phalanx has an unusual proximal surface whose ventral portion projects further proximally than does its dorsal portion. Of digit IV each specimen preserves only a portion of the slender metacarpal, the proximal half in the holotype and the distal half in IVPP V12594. The existence of an articular surface on the distal end of the latter indicates that phalanges were present, but their number is uncertain.

Coelophysids possess three well-developed medial manual digits, a reduced fourth digit, and at least in *Coelophysis bauri*[16] a vestigial metacarpal V (Fig. S3). Their manual phalangeal formula is 2-3-4-?-0. *Dilophosaurus* closely resembles coelophysids in its manual morphology, including the presence of a vestigial metacarpal V, but also differs in several features including a more slender metacarpal I and proportionally shorter phalanx I-1.

Non-avian tetanurans mostly have three well-developed digits, with a 2-3-4 phalangeal formula corresponding to that of the medial three digits of more basal theropods. A vestigial fourth metacarpal has been reported in several non-avian tetanurans[13, 17, 18]. A number of proposed tetanuran synapomorphies can be identified in the manus under the assumption that the three digits correspond to the medial three digits (I-II-III) of pentadactyl more basal theropods, including ‘metacarpal I’ much shorter than ‘metacarpal II’[13], a substantial, oblique contact between ‘metacarpals I and II’[9], the base of ‘metacarpal III’ set on the palmar surface of ‘metacarpal II’, and ‘metacarpal III’ with a triangular proximal articulation[13].

Interestingly, if one accepts the II-III-IV hypothesis for the three manual digits of tetanuran theropods, most of these tetanuran synapomorphies lose their validity because the same features are seen in metacarpals II-IV of non-tetanuran theropods. The large articular surface on the lateral side of ‘metacarpal I’ is bounded dorsally by an elongate flange in tetanurans (Fig. S3). A similar, slightly shorter flange is seen on metacarpal II in *Limusaurus*, bordering a proportionally slightly smaller articular surface on the lateral side of metacarpal II (Fig. S3). In more basal theropods such as *Herrerasaurus* (Fig. S3) and *Dilophosaurus*, an even shorter flange is present on the dorsolateral corner of metacarpal II and forms an overlapping contact with metacarpal III. Similarly, metacarpal IV of ceratosaurs, *Dilophosaurus*, and more basal theropods is similar to ‘metacarpal III’ of tetanurans in having a sub-triangular proximal outline, in being very slender compared to the more medial metacarpals, and in being set on the palmar surface of the adjacent metacarpal.

Furthermore, metacarpal III has a distinct dorsolateral process on its proximal end in ceratosaurs, *Dilophosaurus*, and more basal theropods, comparable to a similar process on the middle metacarpal of basal tetanurans. These similarities suggest that the three metacarpals of tetanurans correspond to metacarpals II-IV, rather than I-III, of more basal theropods. Finally an extensor pit is absent in metacarpal IV of ceratosaurs, *Dilophosaurus*, and more basal theropods, as in the lateral metacarpal of tetanurans. The absence of an extensor pit is, however, likely to be correlated with the slenderness of the metacarpal and thus may not be good evidence supporting the II-III-IV hypothesis.

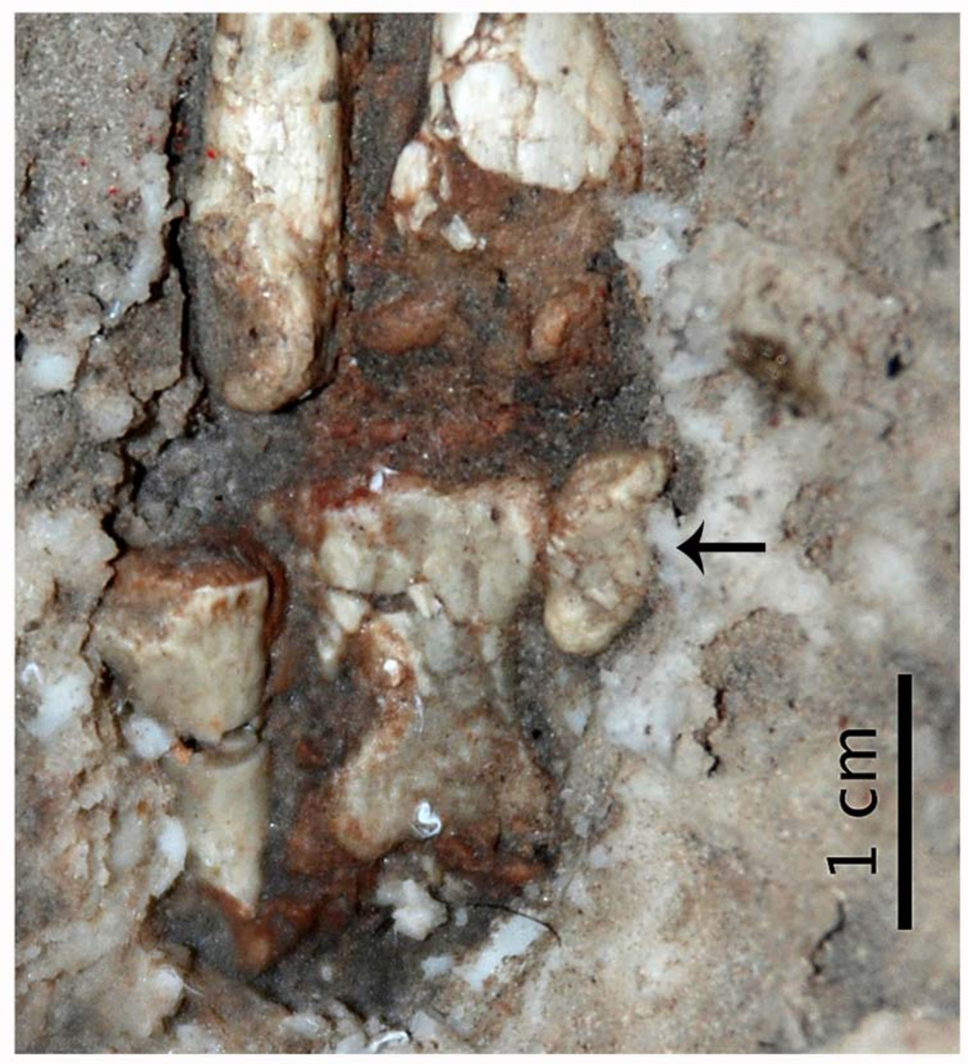

Figure S2. The ventral surface of a partial, articulated left forelimb of *Limusaurus inextricabilis* (IVPP V16134) embedded in silicone. Arrow points to a reduced metacarpal I.

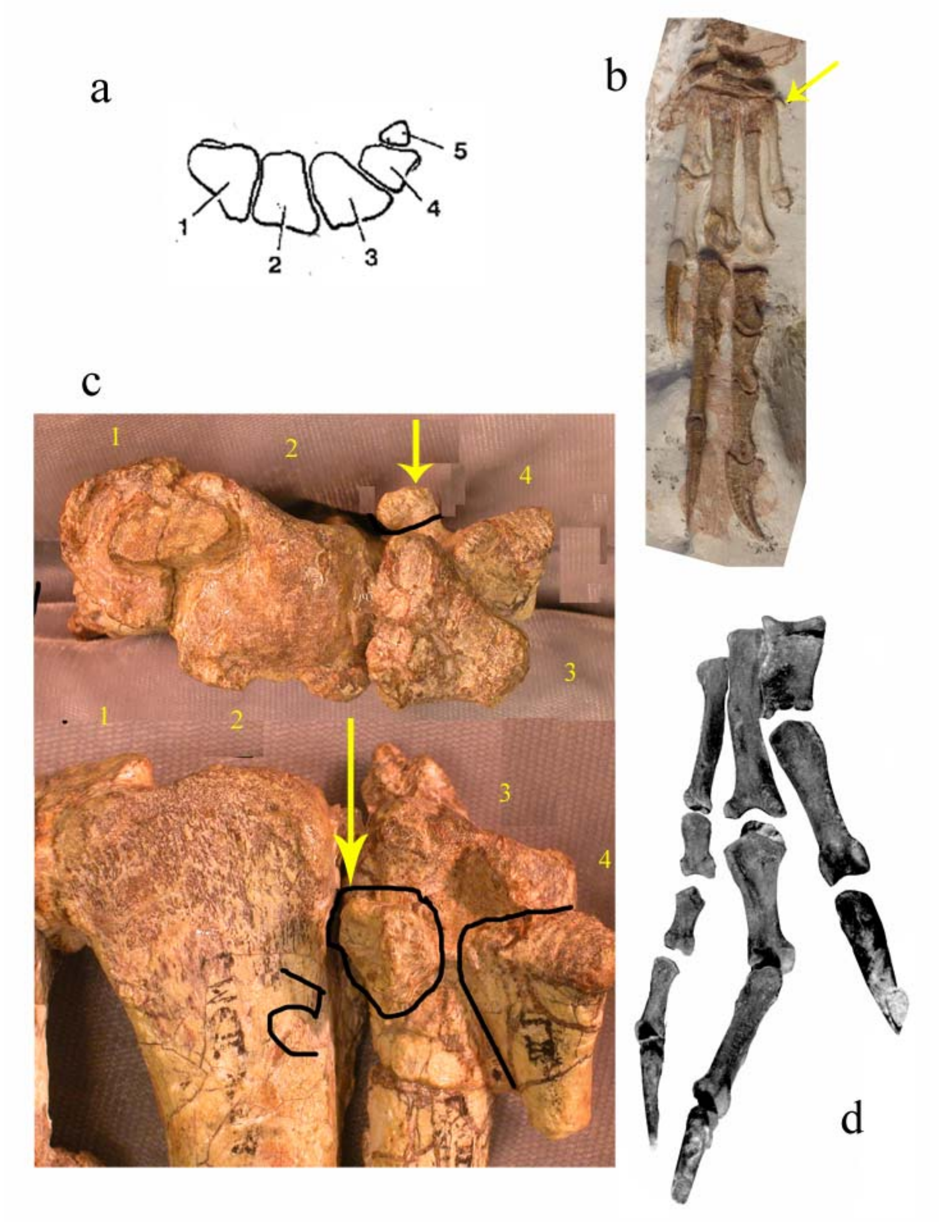

Figure S3. Theropod manual morphologies as represented by several non-avian theropod taxa. **a**, *Herrerasaurus* carpus in proximal view; **b**, *Coelophysis* manus in dorsal view; arrow points to metacarpal V; **c**, *Dilophosaurus* manus in proximal view (top) and ventral view (bottom; image reversed); arrow points to metacarpal V; **d,** *Allosaurus* manus in ventral view.

5. Select measurements of *Limusaurus inextricabilis* holotype

Select measurements (in mm) of *Limusaurus inextricabilis* holotype

Elements		
Mandible length		105
Dentary length		59
Snout length		55
External diameter		17
Antorbital fossa length		26
Posterior cervical vertebra length (C7)		45
Anterior dorsal vertebra length (D4)		26
Anterior caudal vertebra length (C2)		27
Middle caudal vertebra length (C12)		26
Left scapula length		*95
Right humerus length		80
Right radius length		40
Right metacarpal II length		12
Right metacarpal III length		13
Left ilium length		140
Left ischium length		133
Left femur length		208
Left tibiotarsus length		249
Left metatarsal III length		155
Left pedal phalanx III-1	length	36
Left pedal phalanx III-2	length	26
Left pedal phalanx III-3	length	20
Left pedal phalanx III-4	length	21

* indicates the averaged length of the left and right elements

# indicates the estimated complete length of a partial element

6. Phylogenetic analysis.

Character list

Characters 1-353: Taken directly from the Smith et al., 2007 matrix. The following characters were ordered because they contain nested state sets or more than two states, with one state as "absent": 3, 8, 10, 24, 56, 61, 75, 89, 94, 104, 121, 130, 155, 162, 171, 176, 185, 257, 289, 294, 300, 322, 324, 331.

Characters 354-412: Taken from Carrano and Sampson, 2008. The correspondences between this data matrix and the characters from the Carrano and Sampson matrix are listed in parentheses. Character ordering is indicated.

354. External surface of maxilla and nasal (Carrano and Sampson, 2008, #1):
 0 smooth
 1 sculptured

355. External surface of postorbital, lacrimal and jugal (Carrano and Sampson, 2008, 2008, #2): :
 0 smooth
 1 sculptured

356. Maxillary process of premaxilla (Carrano and Sampson, 2008, #3):
 0 well-developed
 1 reduced to a short triangle

357. Subnarial foramen (Carrano and Sampson, 2008, #4):
 0 enclosed
 1 reduced/open dorsally (reduced/open dorsally):

358. Height:length ratio of premaxilla ventral to external naris (Carrano and Sampson, 2008, #5):
 0 .5 to 2.0
 1 greater than 2.0

359. Facet for nasal articulation on maxilla (Carrano and Sampson, 2008, #7):
 0 shallow, anterolateral
 1 socket, lateral

360. Anteroposterior length of maxillary-jugal contact relative to total maxilla length (Carrano and Sampson, 2008, #11):
 0 less than 40%
 1 more than 40%

361. Row of foramina on dorsal nasal surface (Carrano and Sampson, 2008, #13):
 0 absent
 1 present

362. Location of nasal-frontal contact relative to highest point of orbit (Carrano and Sampson, 2008, #15):
 0 anterior
 1 directly above

363. Condition of prefrontal in adults (Carrano and Sampson, 2008, #16):
 0 separate
 1 partly or completely fused

364. Skull roof dorsoventral thickness (Carrano and Sampson, 2008, #18):
 0 thin, relatively flat
 1 thickened

365. Skull roof ornamentation (Carrano and Sampson, 2008, #19)(ordered):
 0 none

1 midline
2 lateral

366. Orientation of posterior edge of postorbital (Carrano and Sampson, 2008, #26):
0 vertical
1 sloped anteroventrally

367. Morphology of dorsalmost postorbital-squamosal contact (Carrano and Sampson, 2008, #28):
0 smooth
1 knob

368. Appearance of postorbital-squamosal contact in lateral view (Carrano and Sampson, 2008, #29):
0 contact edges visible
1 edges covered by dermal expansions

369. Lacrimal fossa (Carrano and Sampson, 2008, 2008 #31):
0 exposed laterally
1 covered by dermal ossification

370. Morphology of lacrimal along dorsal orbit rim (Carrano and Sampson, 2008, #33):
0 flat
1 raised brow or shelf

371. Morphology of jugal-maxilla contact (Carrano and Sampson, 2008, #34):
0 slot or groove
1 lateral shelf

372. Relative lengths of posterior jugal prongs (Carrano and Sampson, 2008, #36):
0 upper prong much shorter than lower
1 both prongs subequal in length

373. Dorsoventral proportions of quadratojugal prongs for jugal (Carrano and Sampson, 2008, #39):
0 narrow
1 deep

374. Overlap of quadratojugal onto quadrate posteriorly (Carrano and Sampson, 2008, 2008 #40):
0 absent
1 present

375. Ossification of interorbital region (Carrano and Sampson, 2008, #42):
0 weak or absent
1 extensive

376. Vagal canal opening (Carrano and Sampson, 2008, #44):
0 through otoccipital
1 onto occiput

377. Shape of opening for basisphenoid recess (Carrano and Sampson, 2008, #46):
0 ovoid
1 teardrop-shaped

378. Depth of indentation between basal tubera and basisphenoid processes in lateral view (Carrano and Sampson, 2008, #47):
0 deep notch
1 shallow embayment

379. Size of dorsal groove on occipital condyle (Carrano and Sampson, 2008, #49):
0 wide
1 narrow

380. Orientation of basioccipital-basisphenoid suture (Carrano and Sampson, 2008, #50):
0 oblique

1 horizontal

381. Shape of pterygoid articulation with basipterygoid process (Carrano and Sampson, 2008, #54):

0 tab-like

1 acuminate

382. Arrangement of jugal and pterygoid processes of ectopterygoid (Carrano and Sampson, 2008, #55):

0 oblique

1 parallel

383. Proportions of ectopterygoid (Carrano and Sampson, 2008, #56):

0 gracile

1 robust

384. Size of external mandibular fenestra (Carrano and Sampson, 2008, #58):

0 small to moderate

1 large

385. Prongs at anterior end of splenial (Carrano and Sampson, 2008, #62):

0 one

1 two

386. Shape of articulated dentary rami in dorsal view (Carrano and Sampson, 2008, #64):

0 Vshaped

1 U-shaped

387. Position of lateral dentary groove (Carrano and Sampson, 2008, #65):

0 at or above mid-depth

1 in ventral half

388. Visibility of paradental plates in medial view (Carrano and Sampson, 2008, #70):

0 widely exposed

1 obscured

389. Medial groove in paradental plates exposing replacement teeth (Carrano and Sampson, 2008, #71):

0 present

1 absent

390. Length of axial epipophyses (Carrano and Sampson, 2008, #74):

0 moderate

1 long

391. Ventral keel on anterior cervicals (Carrano and Sampson, 2008, #81):

0 present

1 faint or absent

392. Length/height ratio of mid-cervical centra (Carrano and Sampson, 2008, #86):

0 less than 3

1 more than 3

393. Height of postaxial cervical neural spines (Carrano and Sampson, 2008, #87):

0 moderate or tall

1 short

394. Accessory fossa on dorsal surface of postaxial cervical transverse processes (Carrano and Sampson, 2008, #88):

0 present

1 absent

395. Shape of dorsal transverse processes in dorsal view (Carrano and Sampson, 2008, #89):

0 rectangular

1 triangular

396. Orientation of ventral margin of mid-sacral centra (Carrano and Sampson, 2008, #95):
0 horizontal
1 arched
397. Dorsal edge of sacral neural spines (Carrano and Sampson, 2008, #96):
0 as thin as remainder of spine
1 thickened
398. Pneumaticity of sacral neural spines (Carrano and Sampson, 2008, #98):
0 weak or absent
1 well developed
399. Proportions of anterior caudal neural arch base relative to centrum proportions (Carrano and Sampson, 2008, #100):
0 smaller
1 equal or greater
400. Contact between cervical vertebrae and cervical ribs in adults (Carrano and Sampson, 2008, #102):
0 separate
1 fused
401. Wing-like process at the base of the anterior cervical rib shafts (Carrano and Sampson, 2008, #103):
0 absent
1 present
402. Bifurcate cervical rib shafts (Carrano and Sampson, 2008, #104):
0 absent
1 present
403. Spacing between glenoid and posteroventral process of coracoid (Carrano and Sampson, 2008, #107):
0 moderate
1 close
404. Size of coracoid (Carrano and Sampson, 2008, #108):
0 shallow
1 deep
405. Longitudinal torsion of humeral shaft (Carrano and Sampson, 2008, #112):
0 absent
1 present
406. Length of humerus relative to femur length (Carrano and Sampson, 2008, #114):
0 >1/3
1 <1/3
407. Contacts between pelvic elements in adults (Carrano and Sampson, 2008, #116):
0 separate
1 fused
408. Shape of dorsal margin of iliac postacetabular process (Carrano and Sampson, 2008, #120):
0 convex
1 straight
409. Morphology of dorsal surface of pubic boot on midline (Carrano and Sampson, 2008, #126):
0 convex
1 concave
410. Morphology of anterolateral muscle attachments on the proximal femur (Carrono and Sampson, #132):

0 continuous trochanteric shelf
1 distinct lesser trochanter and attachment bulge (this state includes derived coelurosaurs with a trochanteric crest):

411. Development of medial epicondyle of femur (Carrano and Sampson, 2008, #133):
0 rounded
1 ridge
2 long flange

412. Morphology and orientation of femoral tibiofibularis crest (Carrano and Sampson, 2008, #134):
0 narrow, longitudinal
1 broad, oblique

Character 413: was added by the authors.

413. Manual digit 1 (ordered)
0 fully developed, with 2 phalanges
1 metacarpal reduced, no phalanges
2 absent

Matrix

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Acrocanthosaurus

1020000111??0001001100101000101 1?000?11010--?2111011001110111?10000010?00000100
012100000[0 1]1100?0100001101?11[0
1]0000011002??010000001??110010?1?1100101011120 0010?200000100 2110?1???0010?[1 2
3]0??0?1?0?0??100110?0????????0110001000000000000000111110101 1010000???0??????????
??0??????????[0
1]00?1000000101000110?20??0110?01???21???????0??1??10?0011?0000000?1201?00000?000
??00?00002000010010????1????0??0???????????????0011????00?
Afrovenator 1?20?????[1 2]???????????0?210000-1100000?????????1?1?110?000[0
1]01????????001100???00?1?????002??0
001011101101?100200?00??0[0
1]?10?1??????00?0???????0000?001?0?0??????????????????00000????????11110????0????000
00?0??0?00100[0
1]010011100?0??0110?0000101000110?201?0????0??002??0???01???111?02?0110?1???10?12
01??????0?00???00?????000000????????????????????00??????????????00?1???
Allosaurus
10200002010100010011001210001011000001 1010--12101111000100111010000000000000100
0121000001110000101011101011110000110020100000000111110010111011000111011 00010
0100000100111001000100200100000000010111010?01?????011000100000000000000111110
1011010000000010000100100101001100000100110000001010001101201101101012002100 10
0010101111020011001000112010000000000000000000000000000101000100000001100000
00000000100001000
Archaeopteryx 0020?10[0 1 2 3][0
1]2???10?1?1?00?0?10?111???01?0???0--??10100011?????13?10??0?0??20?2???00?[0
1]01???0?0?102?1????01?????00????2??13???1?000001?01?0?00?11????1?1110020?1?1??????
???0[0
1]??0???100??0?2??????111?10???0?11100?11??1111111111??100?01?00110----11100??0--0-1
110201??11100211021?010?1201?10?0102110-2?11??312?10???????????????1??[0
1]2?110?0211?100???0????1???0??????00??0?00??0010000????????????????????????????????
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Aucasaurus ????????????????????????2???0??????0?????2???????????????0???????1???0???????
??1??????
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2]??????????????2??????????????0????1???1?1?1????????????????????????????1??1?????1?????
??1??1?????0??????????1???????????????1??1??????1??????111?1?????0???????0??111???????
11?1111????2???1?1??????????????????????1?????1???0111?1?1?1?
Baryonyx
10??0103120?01?0?10?10?20000????21?10?01??00?2??0?11000001020-0100??000??0?01?????
??0?00001000?0000000?10?1001?0????????010010211111 1????????1001011101?01010?20000
01?01010?1?100010?????????0????????????0????????[0
1]0?0001001020000001 1???????????????0?01000????????10??010??1?00????0?0?00000001??0
1101?????010?????????0110?????????02???????????????????110111????1??????????00???????
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Berberosaurus ???
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1100???
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Carcharodontosaurus
102?????????????1??1????110000-1?0000?11010--?21?10110?111?111?1???1110?01?001??????

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Carnotaurus
101120010???00010011000110000-01?000110120--120010101112001130101100 1?0011111100
11-0100020100?1?0000000100?010100110??0111110000?100100100100110001010020101012
110021102100?10100111131?-110?0?1???12?00???????0??0011001001101010001 0???000?000
0?[0
1]00??????010000100110001210200110000110100010011000000201?11010111??????11??????
????1?????????????????????000?0011111111011211111111101??10111111111011101011111 0110
1111111111
Ceratosaurus
10112000021100010011000110000-0100000101210 0?20011110001000101100000000000001000
0011001000211000110 0?000010010101 0??1000?1111000000010110010010011000101 0020[0
1]010020000010011001 1?1000010310-1100000000010000 0????????0011000001000010000 0??
??0010000?010??0???010?0010?1?000121020011000011??00010011000001200101010111 10[1
2]10?110010?011101200??000100001??0???0???0000001100000000000000001?1000011010001
1100010??01000111101[0 1]111
Coelophysis_bauri
000011111201010111011100101 10?000010000010--100?010000000001010000000 0?00000?00
001000?00?0000?010?000??1???00?00?10??1?100?0101???000000000000110?100001100000 1
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1]200?1?000000020??110000000000000 00????????0000000000000000000?1-00010?001??000
00?0000000100111000110200100010000001000010000001100?000100111011?111000000000
0100[0
1]11000?100010100000000000000??0?0000?0000000????????????0??0????11??0??????-01?11?1?
?0
Coelophysis_rhodesiensis
000011111201010111011100101 10?000010000010--100?010000000001010000000000000000 00
?0100000?1000000100000011001000 00?10??1?10??01010??00000?0000001100100001 1?0?001
000000001200?100000000200011000000000000 00??????????000000000000000 0?0001-000101
0010000000000000000100111000110200100010000001000010000001100?010?00111011?1110
0000000001101110?011?0?1010?00000000??
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Coelurus ??
???11100?10111[0
1]1??0?1???10100[1 2]?0[0 1]0?1????????0???000?01?????????????????0????00000000[0
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1]??????????????????????1001110?????????0?101211101?????20121?011??2[0 1][1
2]111000?00???????0001??????000000???????????????????????????????????????1110???1?????
1?0??1??0
Compsognathus 00[1
2]00?11?2???????1?1????011001??????1?????0--??0?1??0000????1???0????0??2??0???????????
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1]??????1???0??01????????????????????0000???1?0??0????1??0?11100?0?1???10??00??0[0
1]0?????010??????????0?0??000?01?10?01?00--?011??0?00???0??00?00???11?10?0?????1?000
0[0
1]?10????01????1?2????????????11?00??10000???????????????????2?????0???????????001??0?
??0?0??2???0??????00??00000?0000000?00?????????0-0?001??01??1??1???00?000?1??0

Condorraptor ??
??11100?010100200
000???1110?11???????[2
3]01??00?0?0?00?201???0???????????000
0???????0000????0??0?01???????[1 2 3
4]???01?01002????????????????????0????????101??0???????0?????????????????????????????
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Confuciusornis
00-00104-2??010----?0000--000?????---00??0--?01?1??0110???11301000??01??00?0?0000[0
1]0??-?????1?????????????????????2??????000000--1??1?0?00?1??????????00?0??1?0?0??01?0
1[1 2][0
1]?1?-?100?11?30??10?1?1010?0??????11?11111111111-1-?0100001100111----?1100??0--0-11
102012?1110021102?--?0?1201?0-0?102--0211111?412?10????????????01102120110?1?11110
0???1?????0??0??????00??0?00??0010000???1??2
Cryolophosaurus 10[1
2]??????????????????????????????0?010?111?20?1?1100000001010000000000000010001210
11001110000100000????000?0???00??????????????1101101101????11100[0
1]0?0??0??0?00?00[0
1]0???1010??010???1?00????0?0?00000???????????????????00??0?00????????????????????????
0????0??01????0?1??0?0000??????0????0?00000011001010 0????10[1
2]10???00001000001?????????????????????000?0000????000?0200000000?????0??????????????
?1?000???????0??100?
Deinonychus 0?2000010???00????1100??1?0011110?0100[0
1]01????01010001??100112???????010000???00100010????0?0?1????????0?1?????????1[0
1]11311???00000011?00?0-?1??1??1111100201011?20??01?01211??20101111?????1???1?0120
0101111???????10?1?11111001010?110?1101011111111110100111110 22?1110021102010100?
??0??0?111011?21?????312110??101????1?001102121110002001101-001011110?01000000001
?0000????1000?0101??????0101?00??110010????????11000?1100
Deltadromeus ??
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???1???????????????0??1?????11????1?111???????0????
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Dilong 0020200101??????021?001010001011??00?1011111?21?101100010?0?[1
2]00000000?[0 1]?0020000?1210-?1?[0
1]01?0?0?000?00021?1???0??????????100000011?110?1??11??????11100?0?010010??01??0[1
2]0?????0[0
1]???????????????10????????0??????0???10000010200?0?0????????1011011111?0?00??001110??
?1100??????1000??[1 2]0??11000??100[0 1][0
1]?11??20??????101??????0???????????????00?????????????2??????????00??0001010210001 0?0?
??0??0???0??0???????????????????????????0

Dilophosaurus_sinensis 1?2120[0 1][0 1]0[1 2]????1??[0
1]?1111110100??1??0??11?1111?20????10?000001?100000000?000001000100011?0???00???1
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Dilophosaurus_wetherilli 101?11111[1
2]01111101011 1?010100?0100000010?111?20?10??0?0?0?0101??000?00000000?0?01?00?100
10000001?00000010?100000??0?????0?001001??01101101?11011001010010100?010000000?1

000?10100001020?00000000000000?000????????000?0000000000000000???000101001000000
000000000?00100000011020000?0001100?0000010000001101101000011101101110000100000
?10011000000001020?0000000000??1?0??0?10000?0100???000???00?00?0?01????00???10100
0?1000
Dracovenator ????1101?2?111110001???[1
2]1??1???????0??
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Dubreuillosaurus 1?2001010[1
2]0?0???001100?210000-?100000????????210????000001?11100?00000110000?000120000??[1
2]01000?0?0000001?1?000?0????02?????00000111???????????????111???0???????????1??1?10
???1????00[2 3]0?0000?0?0?0??01?0?0??????????1100?0[0
1]????????0????????????????????0?00??0?0012????[0
1]0??????????01???????????????????????????20?????????00??00????00000000?0????0???00?0
?00??1??????????????????????
Ekrixinatosaurus ???????????????????????0???0??????0??????????????????????????????1???1???
???111???1?1?
01???????1????????????[1
2]???0??????????1???1??1?????1????1?
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??1??1???00??1??????1???????????10??001??????0??????11?11??
Elaphrosaurus ??
??10[0 1]00[1
2]110000000?00???021011?010001030?-110?0?000?010?????????????0??001001101010???0??
??????????0????????011?00100110001010200100 20?0???0?0000010000012011000000011111210
011??1???100?1100??1001000?0??????????0???????????????????????????????????????1111101?
01??111010?10??
Eustreptospondylus
102001?1020?0???00110??210000-1100000?????????????10000?01?1100?????001100????001?
??0?0?201????0???00001?110000?????????0??01?011????????????0000011101101?100200000
???1001?1?10??000?0????0?000???000??????????????1?0????1000000??????????????????????
??0????01?0100?0100?11??0?10??100?0???00??011?1201101101012002 1?0110?1010111??2??
??0?100???1??0??0????0???
Giganotosaurus
102????1????????00??00?110000?11?0000110?0--?2????1100111??11?10??11100010001??????
?0?0?011?000-

111?0????01010111????[1 2]??????2000????1????11101001010111?0[0
1]?101200?00???21???1010??1??20??001000000?000100???????????1000100????????????????
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???1????????????????????????????????0???
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Ilokelesia ???1?????????????1?0?01????
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1]0101201?0211?[0
1]1???1?1???111????????0?1??0?200?00??
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???1?1????????1??????????101??????????????????????1010?????011???????????
Irritator

1?20????12????????????1200000-??2??1??011100?20?0?110000010200??000000??000010??12
0011??0010000000000?10?1001?0???????????0????1??110??????????????????????????????
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Liliensternus ?????????[1
2]?????????????01??1??0????00?????????0?1??????????????????????000?0????1???0?0?100???
0??????????????????????1?10???1001???0??????????????110000100000100000000?100011??00
0000?0???0??0000??000??0???????????00000000000000?00???0???1????0????0?00000??0??0
1100001102000000000000010000?00000?110010000001101100?100000000010?0??0000100
?1??0??0000?00???11?0???????????01?????
Limusaurus 00-011?4-2[0 1]?0101---100?210?01100??---000[0
2]0--?0??1?10000100010??-0???00010010??0?-1
1--1??00?000??1?0110?10100?1?0?0000?000?00?2?????100??????????0?0?00000100?1100?--1
0?00100011010-100010[0
1]0---1---0100?110-?1-0000000210010?100?1?2?????000?101000000?10000??2???0?0????????
????100??1?1?????001110??00???12?100-00-?-001?00000000000000?00?????????1??---0111?1
???0100110-?101??1
Majungasaurus
101120010211000100110001100000-010000110120--?2001010111210113010110010?01011110
011-0?0?020100?1?000000?10?101?10?110?001111100000?1001001001001100?10??020101012
0100211011000?1?100?11131??110???0???12?0??0????????011??1??11?101?????????????????
?????????01000??0?1100?121?20011??????????????????0???2?1??????1?11?2???11?11?1?111?
1??0??0?01????1??1?1?????0?111111011111011011111111111111111011101011111011011?
?111??1
Mapusaurus
1???????????????????00?110000-11000001??10--?21?1011?01110111????????0?01???????????
??100?????????????????????????????????????200?111?10010?1?????1010111200010120000???
21??01?1000??0????????000001001???0?????????1?00????1??0?00???0???????0?0???????0?00
01000????100101?01??000????????0?00?01000120?2011111010?200210011010?0?111???0?1
0?1000101??0???????0???
Masiakasaurus ?0?????????????????1????110010?01112?0?????????????????0?0???????0???0??0
00??????????????????????????0?????1????????????????11110-000?00?????????11?0?10100201010
11000121???000?1010001??[2
3]0??11??0?0?00010?????????????0????1??11010????????????????????????0?000?

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0??0??1??1?10????0?01?1?1??000010001?????1?101???11001111010?111101??1??1?1121?
Megaraptor ???
???10111?01?10120000
0????????????????????????1?0?????0??00???????????0?000100???????00?000100110100?01000
0100?????????????0?0??????00[1
2]0011???0????????101??????1111?0???????
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Monolophosaurus 1?2000010[1
2]??0011?0?1001210000-?1000??11?1101?21?1001000000011-110000000100?0100012100100
00000?01000001?10??00??0???????101000000111110?10????0??1?1110??0?01?020?000?0001
?0?1?100??0020????0?0?0???0??010?
001001??[0
1]011111000?0000???00?0000000???0???
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Neovenator ?0??00020201000??0?100?21000101?00000?1010--??????????????????????????????
??0?00??????????????????1?????????????
?0????021?0?1?100010???????0?0?0?010??10?0??????????1??????????????????????????????????
??????010??????1??1?1?0??00?0?[1
2]00?100??0?10?0001101201101?010120?2??01100???????????0??00?00?101120??0????0?0??
?00??1??0
NMV_P186076 ??
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Noasaurus ?????????????????????0?110010?0111200???????????????????????????????????????
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2]0??10121001211??0??
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Ornitholestes
0?20000101???00?121100?011011111??00??0010--????10100?010?012??000?000000020?0000
2010?0110111?0????????1?????????????[2 3]?10?00?00011?1000[0
1]0?11??????11100?01?110100?01???101??2??00010020??0?0?0?000?0?01?1?????????0??????
??00001001?00???101111111??0010?00111?0???110021100?1000??200????-?00100[0
1]0??1????111?0??????????01?00??????????00??0010001?1??????000?0000??000??1001?0000
10???????????00?0???01?????0?????1000?1??0
Piatnitzkysaurus ?????????[1
2]?????????????110000-1100000????????????????0???????1000?0??????????????????????0100
0???0000001011000?0????????????00?0?????????????011101[0
1]1001010100200000???1110?1110000102?1100??0?????????????????????010001000000000000
00??????????????????????0?0??010?1??00000110000000?11000000001000

01012011011010121021 00??0?????1??????0??001000101??????000?00???????????????????????
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Rugops ??????????????????1????0???0?????00?1??12????2????????1?1???????0?????????101??
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Segisaurus ??
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??0??????????????0??????000???00?000??????????101000001??000?0?????????????????????0?00
0????????????????02?????010?000????00?0?0?????????10?0??1?????1110?????????????1?00??
?0???010??00????0??00???????01?0?????0
Shenzhousaurus ????0004-1???0???-??00?0110010???1-1?00010--??1-??000??????1-??0000??0
????00?0100??-0?-??-?---?????????--????????1??--??010001-01????1??-?1?????-??-?????--?????
???-??-[0
1]0???-?10--?-?20??0??-0?00-0??0?01?---??--?-??----?-????-??--??---1??????1???0??1000011001
?-11001110102[0 1]001[0
1]?00?100000110-00?11-120110??-??????????????00????
?00??0?0000??????????????????????????????0???????00?1?00
Sinornithomimus
00??0004-10?000??-?1?010??0??0?10?-??00010--?0??1?000??10011??1000000?020000001?021

0001?0010??????????????????0?????????010?01-?1???01?111??0?0?0111?00?01?11?100002?0
1100?0??10?010?30????0???0??001??011????????1111001021001000 1?00???00111101111001
1000011001???1?0111?1?2?001?200?1000[0
1]0110100111?1201101001012012?001?00212?11000200-?00?000?0?1[1
2]0?0?000?00???0
Sinosauropteryx 0020000[1
2]01??????1?1????0??0?1?????01???010--????1??00??????11???????????0?????0?02????10????
?????????????????????????????????00??????????????????11?00???1???10??01?002??????010?
???2??????000000011?11101000--?0111001000000??00?00?011111[0
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1]??0?0??????????????0??12??1????001?00???0????[1
2]0??0???0
Sinraptor
10210011010100010011001010001011000001101 0--12111011000110111?10000110000000100
0121000001110000110110101001000000110020100000000111010010111010010111011000 10
020000010?1110?10100010020??000000000?00???10?????1?001100??????????????????????01
0??010??0?000100001001001010011000001001100000001010001101201101111012102100110 0
1010111102001100100010112010 0???00?0000000?100000001000 0??0?1?0101?000?1000??100
????????0001000
Spinostropheus ??
??2???0?0?0?
?0?????0??????????113???1???????????????????????????????????0???1???????????????????????
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???11011?11?000???????????
Streptospondylus ???

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2???
Suchomimus ?02001031[1
2]0?01?0010?101200?00-1?2111??0??????????????000?????0???00????0???00???????0????0???
?????????????????????????????01001021???1?????????1001011???????????2????0??0[0
1]01?0101000100??????????????????0???????????00???0100102000000 11????????????010??010
0010000?00100[0 1]????1??00?0[1
2]00?00?00?0?0100011012011001?1?12??2??0110??010?1????????????0????????????110?11????
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Syntarsus_kayentakae
00001111120?010?1101110110110?010010?0001110?10?0100000000010100000000000000000
000000000100000001000000110010000 0??00?1?1001010110 1?010000000001100100001 1?0?00
100000?001200?10000000020??11000000000000000????????000100000?0000000??0???0??1??
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0000000110111 0?011?0??020?00????0???
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Torvosaurus 1???01000[1
2]0100?1000100?21?000?1100000????????2001?100??00101????????001100??????????0?0?2??
??????????????????????????????????0??0??????????????100??11101101?100200000???211001?1
0001?020????0?0000?000?0??????????????1??????10200000010???0111010??000??0100010?00
?001000010011100?000011000000000000??10???1????01012002100110010101110 02?0??00100
010???????010?00???0?000???0
Tugulusaurus ???

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???11??????1????0?0
0???????????????????????????????0?????????001012??101??101200210?????20[0
1]1110002????????????????0??????0???
???1000
Tyrannosaurus
10202001010?000?02110010110010110100000110--12111011011100112010000010011020000
012101010001002010000000211110000110?31101000000111110011?1101001011100201010
?20000110021100101000100 2?0100000100000101011??1?????010000100100100000 10??-0011
1??1?1??0-0000011101?0010011100110001110011000001100211110121110110101201210011
00212111000200??-0-000001120?0000000000??0?0001001000000 10?1??10?1?0000010100101
10000000110011100
Tyrannotitan ?0??????????????????????????????????0?????????21[0
1]1???????????????????????????????????1??2000?????
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3]?????0?0????00??1???????????????000100???????0[0
1]????????????????????????0??000??????????????????0?0011??00[0 1][0
1]1010?012?120110110?????????????00????????????????0?????????0?[0
1]0????0??0?????????????????????????????????00?????0??????????0?1??01???
Velociraptor 0020000[0
1]010?000??01100101100111101 01-00010--?01010001101001130100000010000200001[0
1]0010-0100101101000001011?10000001?11311?10000000?1?00000?1?01??1?11100??101????
?0?1??111?00201011?1?30011001110120010111111 0??01101111111 10??0100110011010 1111
1111?0010011111022?11100211020101001200110011101102111111 3121?0001

01201210001102121110002101101?001011110?010000??00??0000??00100000???????????????
????????????????01?????1000
Zupaysaurus 0?10?????[1
2]?????1??????0010110??1?010?000?110?20?101?00000001010000000?0000000000120011001
00?????0???????????????????????00101001???010?10?11????0?????????????????0???????????
???1????
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Analysis and results

The data matrix (65 taxa, 413 morphological characters) was assembled using Mesquite v. 2.5[19], using character statements from the datasets of Smith et al.[20] and Carrano and Sampson[21]. These datasets were selected because of their dense sampling of the Ceratosauria and because they also included theropod taxa that bracket the Ceratosauria. Some characters in these two datasets contained either nested character state sets or three or more states where one state was "absent". These characters were considered ordered in our analysis, and are marked as such in the character list. Manual digital characters were scored as "I-III" for all tetanurans including birds.

Phylogenetic analysis of the three data matrices was conducted in TNT[22]. Trees were rooted on *Marasuchus*. The following heuristic search settings were used to generate most-parsimonious trees (MPTs): hold 10,000 trees, 5000 Wagner builds, retain 3 trees per replication, with tree bisection and reconnection (TBR) as the search strategy. Heuristic searches recovered 1882 MPTs of length 1093. The strict consensus tree is shown in Figure S4.

The taxa (*Limusaurus* + *Elaphrosaurus*), *Deltadromeus* and *Spinostropheus* are unresolved at the base of Ceratosauria. It is likely that *Spinostropheus* is closely related to *Elaphrosaurus*, based on the presence of a dorsal diapophyseal fossa on each cervical bertebra[21]. More skeletal remains of *Spinostropheus* would likely help resolve its position. *Deltadromeus* was initially described as a coelurosaur, but was assigned to the Ceratosauria by Carrano and Sampson[21]. Its basal position in our phylogeny is in accord with their results. The basal position of *Deltadromeus* may, however, reflect a lack of character data. Personal inspection of *Deltadromeus* was outside the scope of this research and we were thus unable to score many of the characters derived from the Smith et al. matrix. *Elaphrosaurus* and *Limusaurus* are recovered in all MPTs as sister taxa, although they share only one synapomorphy in this data matrix: cervical ribs fused to their corresponding vertebrae. This character is also present in more derived ceratosaurs (including *Ceratosaurus*), and this sister-taxon relationship is likely to be labile given more character data for *Elaphrosaurus*. Further osteological comparisons between *Elaphrosaurus*, *Deltadromeus*, *Spinostropheus* and *Limusaurus* are needed to resolve phylogenetic relationships at the base of the Ceratosauria.

The following synapomorphies support the monophyly of the Ceratosauria in some or all of the fundamental cladograms:

Synapomorphies for the Ceratosauria: 41.2, 56.1, 75.2, 152.2, 182.3, 186.1, 187.1, 220.1, 225.1, 273.1, 282.1, 290.1, 336.1, 398.1, 404.1, 407.1, 413.1

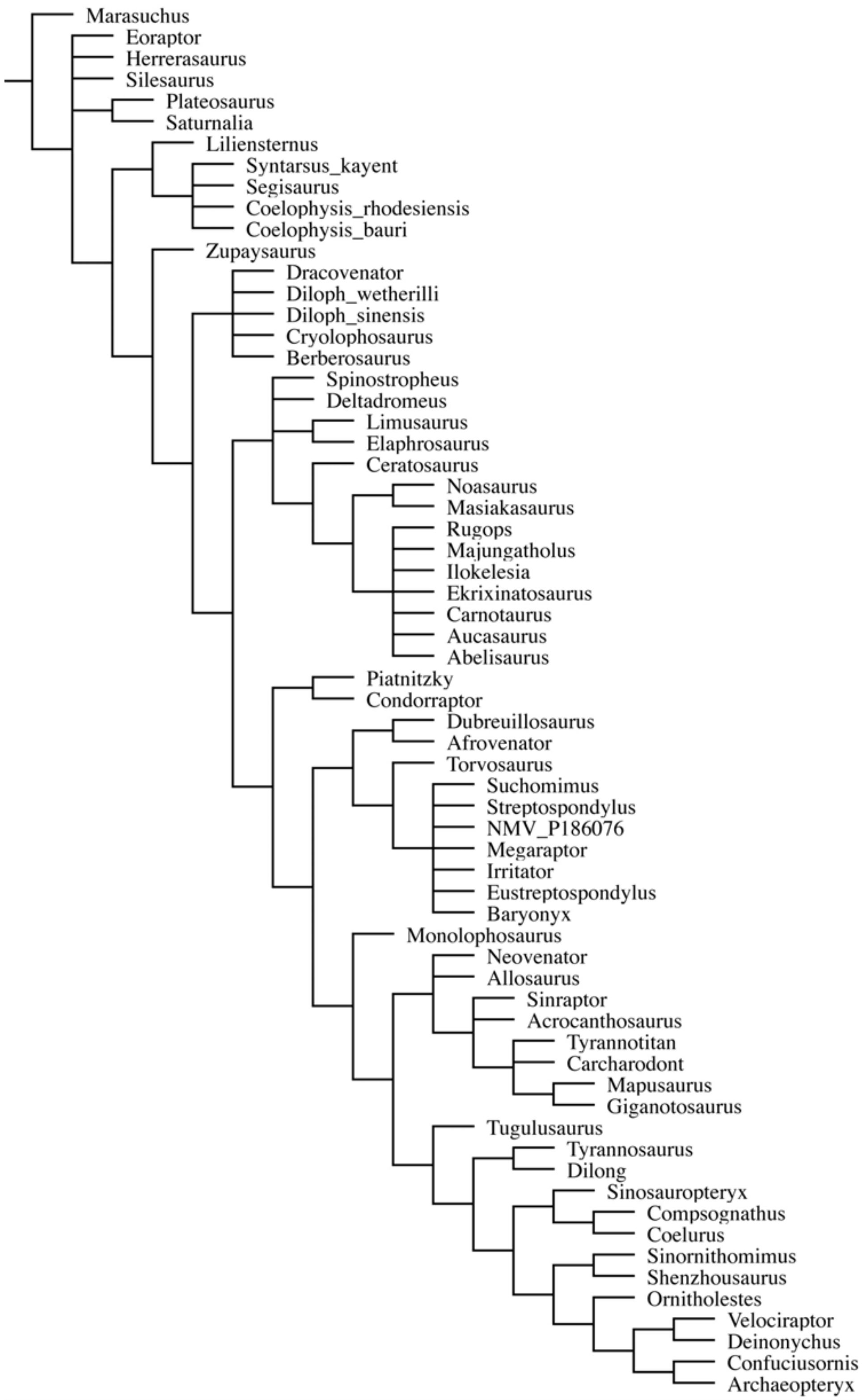

Figure S4. Strict consensus of 1882 most parsimonious trees (tree length = 1093, CI=0.44, RI=0.74)

7. Quantitative analysis of digital homologies

The problem of digital homologies is an example of the larger problem of homologizing serially repetitive structures, such as vertebrae. Multiple hypotheses of primary homology[23] specifying the structures considered to be homologous may be possible, and a choice is typically made prior to a phylogenetic analysis on the basis of the similarity of the structures in position, composition, and connectivity[24]. A quantitative method of evaluating correspondences of repeated morphological structures between taxa is suggested by comparison with sequence alignment of molecular sequences when sequence length varies[25, 26]. When different alignments of nucleotide or amino acid positions have different phylogenetic implications the alignments may be tested by congruence with other characters on a phylogeny[27]. The problem of alternative primary homology statements with the same phylogenetic implications has been little discussed, but can be addressed in the same framework.

The problem of digital homologies in theropods is complex because the developmental and contextual information for one taxon – extant birds – is much more detailed than for extinct taxa. This information strongly implies that living bird digits are II-III-IV[28], whereas the digits of non-avian theropods are interpreted as I-II-III(-IV-V) based exclusively on the morphology of adult skeletons. The digital homologies of basal theropods are unproblematic because *Herrerasaurus*, *Eoraptor*, *Coelophysis bauri*[16] and *Dilophosaurus* (see above) have five digits (although V comprises only a small metacarpal). In Ceratosauria, however, a manual digit is completely lost, and thus the four remaining digits could correspond to positions I-II-III-IV or II-III-IV-V of the primitive theropod manus, if digit loss is restricted to the anterior and posterior margins of the hand. In tetanurans, if digit loss is constrained to the anterior and posterior margins of the manus, the three digits of these taxa could correspond to positions I-II-III, II-III-IV, or III-IV-V, but the presence of a fourth digital laterally in some taxa (e.g., *Guanlong*, *Sinraptor*) contradicts the latter hypothesis.

Assuming birds are 2-3-4, it is possible to compare alternative "alignments" of digits in other theropods to evaluate the set of primary homologies that maximizes hypotheses of homology and minimizes homoplasy. To address this question, we constructed several data matrices with alternative codings for the digital homologies in theropods. We identified a set of 24 morphological characters and scored these characters for each digit present in the 121 taxa in our analysis (see below). Taxa with five digits therefore were scored for 120 characters. Taxa with fewer than five digits could only be scored for a reduced number of characters, the others were scored as absent or inapplicable. We added these characters (hereafter "dynamic characters") to 397 non-digital characters that did not change their correspondences across datasets (hereafter "static characters") to create separate matrices of equal numbers of characters and taxa that implied differing correspondences between the digits of theropods.

Consideration of all possible primary homology statements for theropod digits is numerically unfeasible given the current lack of appropriate software, a problem also encountered by Ramirez (2007). Thus, for practical reasons we only considered the following subset of the possible "alignments" in this analysis: those implied by shifting topological identity from I-II-III to II-III-IV at various nodes on the theropod tree (schemes 1-11; shown by hollow boxes number 1-11 in Figure S5); a set of correspondences (scheme 12) that aligned the three digits of birds with I-II-III of the tetanuran manus (although this situation is unlikely given the wealth of developmental studies supporting extant birds as II-III-IV[28]); a scenario where the digits of ceratosaurs and non-paravian tetanurans are I-II-III-(IV) and those of paravians are III-IV-V (scheme 13); and a scheme where the digits of ceratosaurs are I-II-III-IV, those of tetanurans are

II-III-IV-(V), and those of paravians are III-IV-V (scheme 14). We did not test alignments that involved loss of the middle digit (e.g. Tetanurans are I-III-IV-(V)).

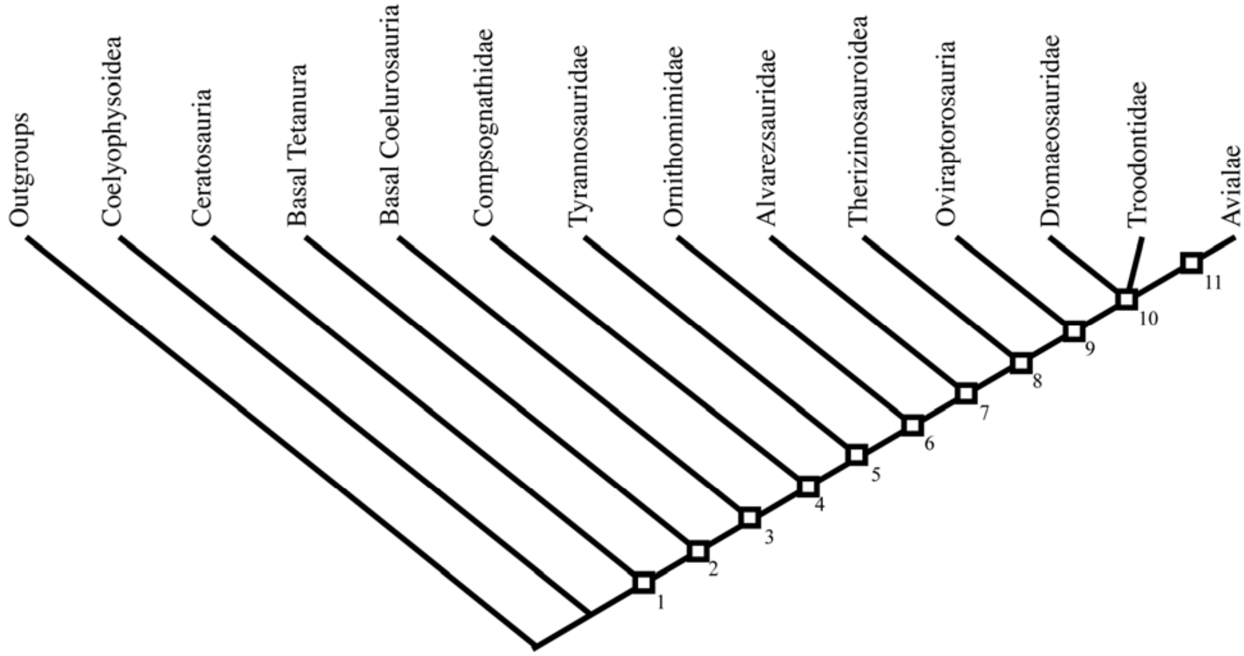

Figure S5. Simplified phylogeny of the Theropoda derived from the analysis in this paper. Hollow squares represent locations of possible shifts in digital correspondence, numbers adjacent to squares are cited in the Figure S6 and in the text.

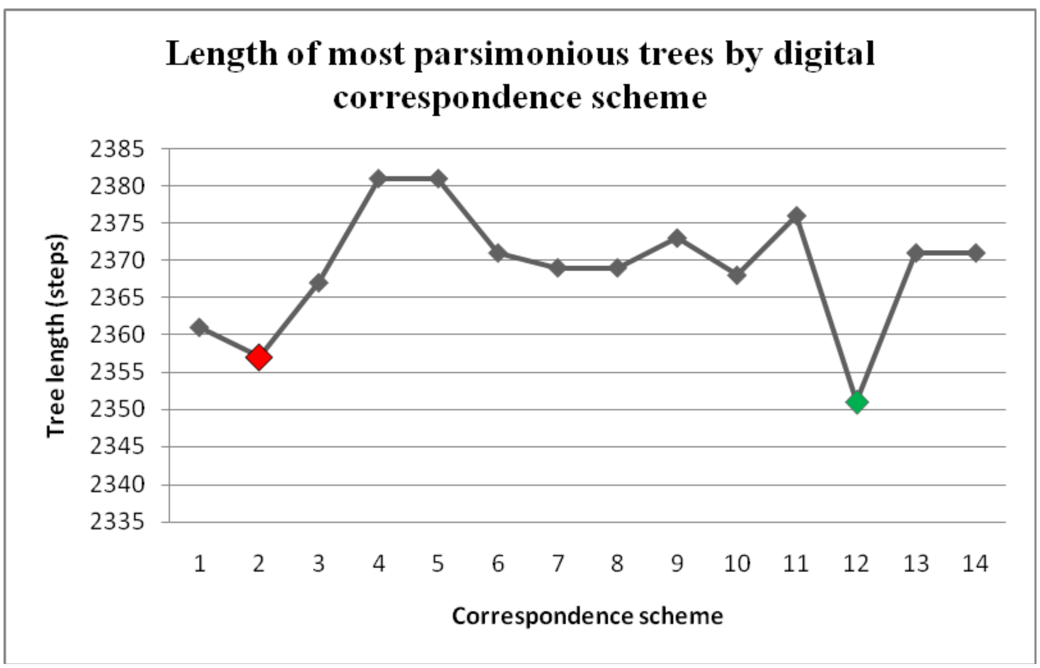

Figure S6. Graph of lengths of most parsimonious trees by correspondence scheme. Correspondence scheme numbers 1-11 (x-axis) are equivalent to node positions on generalized theropod tree shown in Figure S5 and all correspondence schemes are detailed in Table S2.

Shortest tree length (2351) marked by green diamond. Shortest tree length (2357) when Aves are considered II-III-IV marked by a red diamond.

Two basic matrices are supplied in the supplementary information for this study: the "I-II-III" matrix codes the fingers of all theropods with fewer than five digits as corresponding to positions I-II-III(-IV) and the "Tetanura II-III-IV" matrix codes the fingers of all Tetanurae as corresponding to positions II-III-IV(-V). All other matrices analyzed in this study were created using the I-II-III matrix by selecting the descendants of a given node on Figure S5 (constituent species of taxon groups used in this study are indicated in bold in the supplemental matrices), and moving the character scorings laterally by one digit. For example, invoking a correspondence shift at the base of Paraves (node 10, Fig. S5) would involve selecting the characters scored for digits I-III of Dromaeosauridae, Troodontidae and Avialae (characters numbered 398-469; for character number/digit identity see supplementary table 1) and moving them laterally to the character positions for digits II-IV (characters numbered 422-493) in all subtended taxa. This shift implies that digits I and V are absent, therefore characters 398 and 494 (Digit X: absent (0); present (1)) should then be scored as absent and characters 399-421 and 494-517 scored as inapplicable (-).

Digital position	**Characters**
Digit I	398-421
Digit II	422-445
Digit III	446-469
Digit IV	470-493
Digit V	493-517

Table S1. Digital position and related character numbers in this study. Digit number is with reference to the primitive theropod manus, thus "Digit I" corresponds to the thumb (medial digit) of *Herrerasaurus*. Characters numbered as if character set starts at "1," the default setting in Mesquite[19].

Analysis protocol and results

Phylogenetic analysis of the matrices was conducted in TNT[22], using heuristic algorithms designed for large datasets[29]. We used a "driven search" strategy, stabilizing the consensus twice with a factor of 75, and employing the following heuristic search techniques with default settings: sectorial search, ratchet, tree drift, tree fuse. The most parsimonious tree lengths and number of trees for each "alignment" are shown in Tables S2 and S3 using ordered characters and unordered characters, respectively. Following Makovicky et al.[30], we considered *Neuquenraptor argentinus* a junior synonym of *Unenlagia comahuensis*.

The results of our ordered phylogenetic analyses (Table S2) show the shortest length trees are produced using the correspondence scheme where the digits of all theropods are I-II-III. However, as discussed in the text this correspondence scheme is not preferred because it does not explain the available ontogenetic information for the homology of the avian digits. When birds are scored as II-III-IV, the optimal correspondence scheme is produced when the digits of all Tetanurae are identified as II-III-IV(-V) (node 2 in Fig. S5; results summarized in supplemental table S2). This scheme produced 114 most-parsimonious trees (MPTs) of length 2357, CI= 0.25, RI= 0.64. Using this correspondence scheme, 62.5% of the manual digital characters are informative. A correspondence shift from a I-II-III to a II-III-IV identity at the base of Tetanura (node 2 on Fig. S5) is 10 steps shorter than the shortest alignment in which the shift occurs within Tetanura, and four steps shorter than invoking a similar shift at the base of Ceratosauria. This correspondence scheme is six steps longer than when birds and other tetanurans are I-II-III. Correspondence schema where paravians were considered III-IV-V and non-paravian tetanura either as I-II-III and II-III-IV were 14 steps longer than the preferred alignment scheme.

To test whether our character ordering was influencing our phylogenetic results, we reanalyzed each alignment scheme with the characters unordered (results in Table S3). Although the length of the most-parsimonious trees produced without character ordering differed from the ordered analysis, the general pattern of tree length under different alignment schema did not. One notable observation is that without character ordering, the lengths of the MPTs under a Tetanura II-III-IV (node 2) alignment scheme (2286 steps) were the same as the lengths of the MPTs under an alignment scheme where all theropods were I-II-III-(IV)-(V). The phylogenetic relationships recovered using the unordered analysis (not shown) were fully compatible with those produced using ordered characters, although several groups differed in degree of resolution between the two datasets.

Correspondence scheme	Length of Most Parsimonious Trees	Number of Most Parsimonious Trees
1	2361	108
2*	2357	114
3	2367	118
4	2381	80
5	2381	68
6	2371	64
7	2369	82
8	2369	74
9	2373	142
10	2368	103
11	2376	57
All theropods I-II-III (scheme 12)	**2351**	**84**
Paraves III-IV-V (scheme 13)	2371	139
Paraves III-IV-V, Tetanura II-III-IV-(V) (scheme 14)	2371	169

Table S2. Results of phylogenetic analyses using ordered characters under different alignment schema. Data also depicted in Figure S6. Correspondence schemes refer to node numbers of Figure S5 (see supplemental text for explanation). Scheme with shortest MPTs shown in bold. Correspondence scheme entitled “all theropods I-II-III” refers to a set of correspondences where the digits of Avialae are considered positionally homologous to digits I-II-III of the primitive theropod manus. *Alignment where Ceratosaurs are I-II-III-IV and Tetanurans are II-III-IV-(V).

Correspondence scheme	Length of Most Parsimonious Trees	Number of Most Parsimonious Trees
1	2292	96
2*	**2286**	**118**
3	2298	69
4	2312	51
5	2312	61
6	2302	58
7	2301	75
8	2300	71
9	2303	60
10	2301	88
11	2305	89
All theropods I-II-III (scheme 12)	**2286**	**89**
Paraves III-IV-V (scheme 13)	2300	77
Paraves III-IV-V, Tetanura II-III-IV-(V) (scheme 14)	2299	181

Table S3. Results of phylogenetic analyses using unordered characters under different alignment schema. Correspondence schemes refer to node numbers of Figure S5 (see supplemental text for explanation). Schema with shortest MPTs shown in bold. Correspondence scheme entitled "all theropods I-II-III" refers to a set of correspondences where the digits of Avialae are considered positionally homologous to digits I-II-III of the primitive theropod manus. *Alignment where Ceratosaurs are I-II-III-IV and Tetanurans are II-III-IV-(V).

The strict consensus of the trees when tetanurans are II-III-IV (scheme 2; Fig. S7) shows poor resolution for the Ceratosauria. Evaluation of the fundamental cladograms, however, reveals that *Elaphrosaurus* is an unstable taxon, grouping variously with all ceratosaurian taxa. This instability is likely due to the lack of complete skeletal material for *Elaphrosaurus* and the variability of axial characters within the Ceratosauria. A reduced consensus[31] with *Elaphrosaurus* removed (Fig. S8) groups *Limusaurus* sister to *Masiakasaurus* at the base of the Ceratosauria. This is a novel phylogenetic position for *Masiakasaurus*, which was previously recovered as a noasaurid[21, 32, 33]. New information on the *Masiakasaurus* skeleton (Carrano, personal communication) will hopefully clarify this uncertainty. The oviraptorosaurian taxon *Hagryphus* was also removed from the reduced consensus, as its phylogenetic position was highly variable within Oviraptorosauria, Dromaeosauridae and Troodontidae in the fundamental cladograms. Synapomorphies for key groups of interest are shown below (the following unambiguous synapomorphies diagnose their respective clades in all fundamental cladograms):

Ceratosauria :
- Char. 3: 0 --> 1
- Char. 10: 0 --> 1
- Char. 72: 0 --> 1
- Char. 257: 0 --> 1
- Char. 268: 0 --> 1
- Char. 329: 0 --> 1
- Char. 373: 0 --> 1
- Char. 394: 0 --> 2

Tetanurae:
- Char. 36: 0 --> 1

Char. 50: 0 --> 1
Char. 141: 0 --> 1
Char. 190: 0 --> 1
Char. 210: 0 --> 1
Char. 289: 1 --> 0
Char. 358: 1 --> 2
Char. 367: 1 --> 0

Node 4 (Ceratosauria + Tetanura) (see figs. S7 and S8)
Char. 22: 0→1
Char. 114: 0→1

The following unambiguous characters support a sister-group relationship between *Masiakasaurus* and *Limusaurus* (node 3, Fig. S8), but in some fundamental cladograms also support the inclusion of *Elaphrosaurus* as sister to either taxon:
Char. 131: 0→1
Char. 133:0→1
Char. 252:0→1

Implications for digital homology

Based on this study, the most parsimonious alignment is for the four digits of ceratosaurs to be I-II-III-IV and the three (and sometimes four) digits of all Tetanurae to be II-III-IV(V). Accepting such a topological shift at the base of Tetanura requires that the positional homology of the three digits of tetanurans is II-III-IV(-V), as suggested by Wagner and Gauthier[34]. Because the four digits of ceratosaurs are therefore most parsimoniously interpreted as I-II-III-IV, the small lateral metacarpal ossification of *Guanlong*[35], *Sinraptor*[36], and *Coelurus* represents the re-ossification of metacarpal V after it is lost at the base of Ceratosauria. The poor phylogenetic resolution for basal tetanurans in our study precludes us from hypothesizing whether this re-ossification event occurred once or more than once in the evolution of Theropoda. Likewise, the fourth metacarpal, which is reduced in primitive theropods and bears an unknown number of phalanges in Ceratosauria, re-acquires at least three phalanges in Tetanurans.

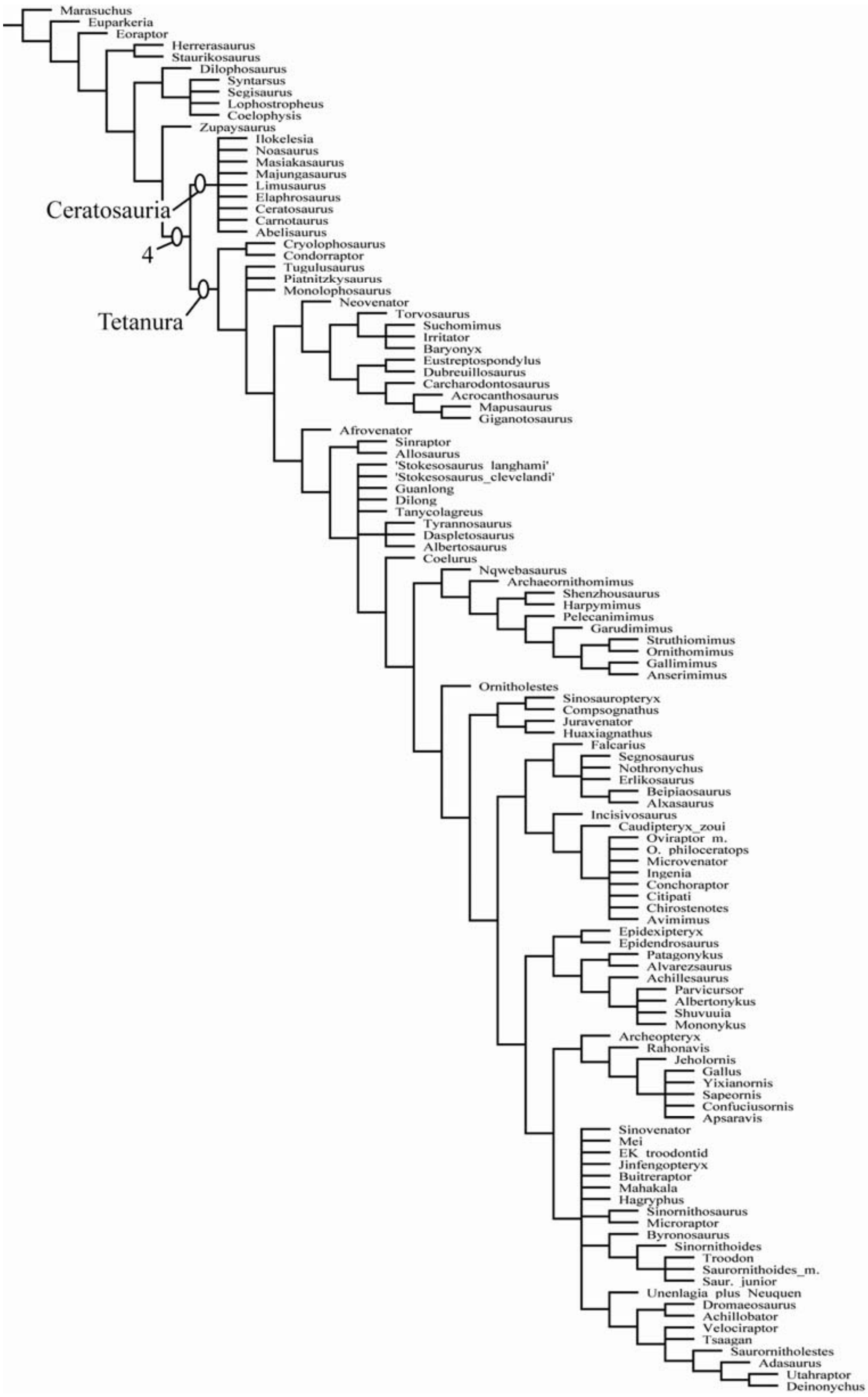

Figure S7. Strict consensus of 114 most-parsimonious trees depicting phylogenetic relationships within Theropoda, when the tetanuran manus is scored as II-III-IV. All fundamental cladograms are length 2340, CI=.25, RI=.64. Labeled ovals refer to nodes of interest (see text). Labeled ovals refer to nodes of interest (see text).

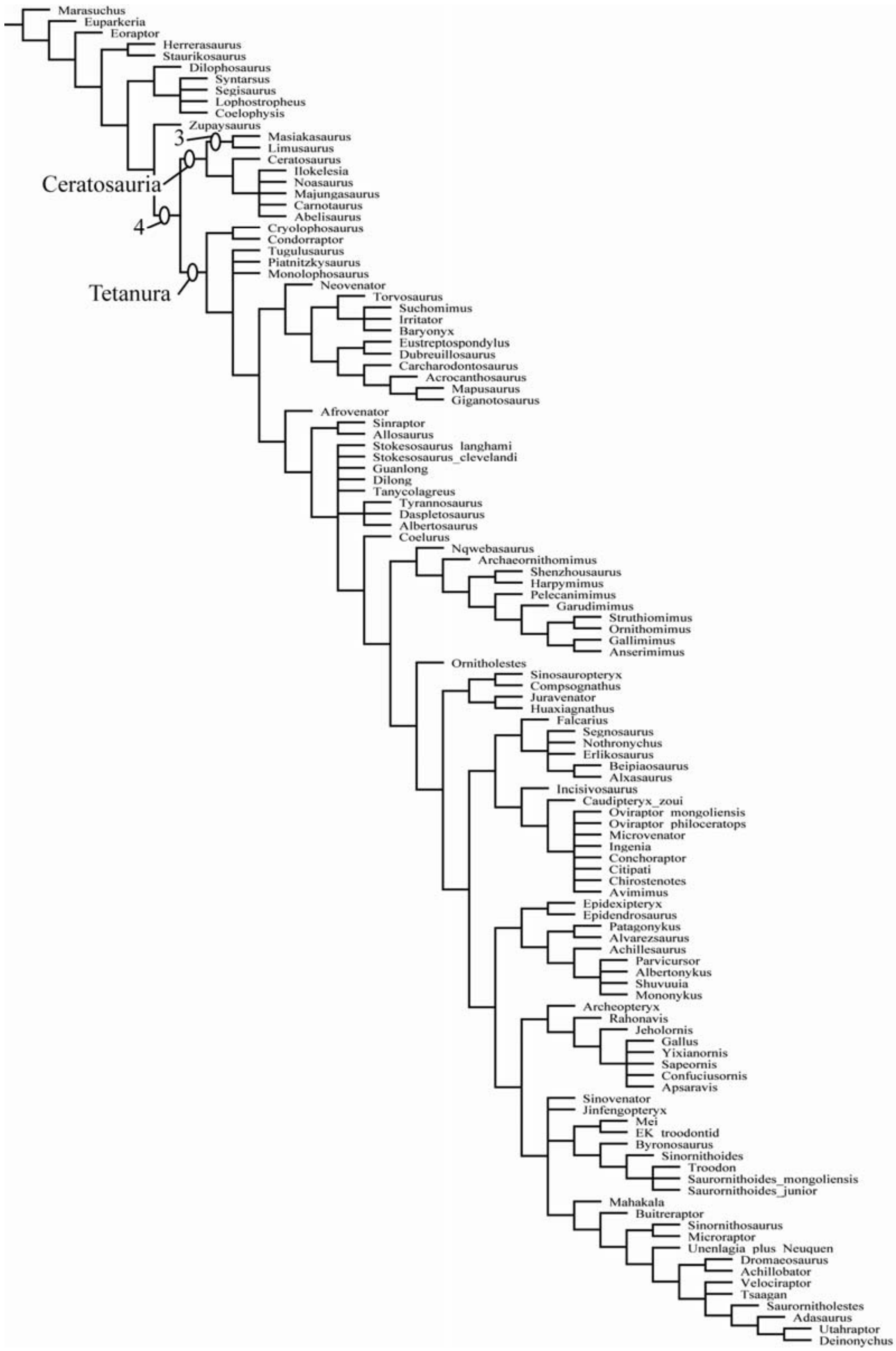

Figure S8. Reduced cladistic consensus cladogram[11] of 114 fundamental cladograms depicting phylogenetic relationships within Theropoda. Taxa removed from cladogram are *Elaphrosaurus* and *Hagryphus*.

Character List.

1. **"Protofeathers"** (A filamentous integument, as preserved in *Sinosauropteryx* and *Dilong*. Separate from the contour feathers character because Rauhut (2003) defined contour feathers as having a central rachis and barbs): (0) absent; (1) present
2. **Contour feathers** (Rauhut, 2003, character #165): (0) absent; (1) present
3. **Vaned feathers on forelimb** (Kirkland et al, character #1): (0) symmetric; (1) asymmetric
4. **Shape of premaxillary body (portion in front of the external naris)** (Rauhut, 2003, character #1): (0) wider than high, or approx. as wide as high; (1) significantly higher than wide
5. **Premaxillary body in front of external nares** (Rauhut, 2003, character #2; certain taxa scored from character 6 of Smith et al 2007 supplementary info): (0) rostrocaudally shorter than body below nares and angle between anterior margin and alveolar margin more than 75 degrees; (1) rostrocaudally longer than body below the nares and angle less than 70 degrees
6. **Ventral process at the posterior end of premaxillary body (give the posterior process a forked appearance in lateral view)** (Rauhut, 2003, character #4; certain taxa scored from character #7, Smith et al (2007) supplementary info): (0) absent; (1) present
7. **Maxillary process of premaxilla** (Kirkland et al, character #20; also Rauhut, 2003, character #6 (with character states in different order): also scored from Smith et al 2007, with states changed): (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
8. **Internarial bar** (Kirkland et al, character #21): (0) dorsoventrally rounded; (1) dorsoventrally flat
9. **Crenulate margin on buccal edge of premaxilla** (Kirkland et al, character #22): (0) absent; (1) present
10. **Caudal margin of naris** (Kirkland et al, character #23): (0) farther rostral than the rostral border of the antorbital fossa; (1) nearly reaching or overlapping the rostral border of the antorbital fossa
11. **Premaxillary symphysis** (Kirkland et al, character #24): (0) acute, V-shaped; (1) rounded, U-shaped
12. **Subnarial foramen:** (0) absent; (1) present
13. **Pronounced maxillary fenestra** (Kirkland et al, character #27, also Rauhut, 2003, character #17 (JNC redefined as "maxillary fenestra"): certain taxa scored from character 29 of Smith et al 2007 supplementary info; originally in Gauthier 1986): (0) absent; (1) present
14. **Accessory antorbital (maxillary) fenestra recessed within a shallow, caudally or caudodorsally open fossa, which is itself located within the maxillary antorbital fossa** (Turner et al #239, see also Witmer, 1997 p43): (0) absent; (1) present
15. **Longitudinal position of maxillary fenestra** (Kirkland et al, character #28 (Redefined JNC 2007; certain taxa scored from character 30 of Smith et al 2007 supplementary info): (0) situated at rostral border of antorbital fossa; (1) situated posterior to rostral border of antorbital fossa
16. **Latitudinal position of maxillary fenestra** (Turner et al, 2007 #237): (0) situated approximately mid-height of the antorbital fossa; (1) displaced dorsally in antorbital fossa
17. **Foramen on caudal edge of interfenestral bar between the maxillary and antorbital fenestrae:** (0) absent; (1) present, pierces ventral portion of bar
18. **Promaxillary fenestra (fenestra promaxillaris)** (Kirkland et al, 2005 #29; also Rauhut, 2003 #16 (promaxillary foramen): (JNC 2007 changed ‘tertiary’ to ‘promaxillary’): certain taxa scored from character 32 of Smith et al 2007 supplementary info; originally in Carpenter 1992): (0) absent; (1) present

19. **Secondary palate formed by** (Kirkland et al, 2005 #25; certain taxa scored from character 34 of Smith et al 2007 supplementary info): (0) premaxilla only; (1) premaxilla, maxilla and vomer
20. **Palatal shelf of maxilla** (Kirkland et al, character #26): (0) flat; (1) with midline ventral "tooth-like" projection
21. **Anteroposterior length of palatal shelf of maxilla;** (0) short; (1) long, with extensive palatal shelves
22. **Orientation of the maxillae towards each other as seen in dorsal view** (Rauhut, 2003, character #10; certain taxa scored from character 23 of Smith et al 2007 supplementary info): (0) acutely angled; (1) subparallel
23. **(ordered) Ascending process of the maxilla** (Rauhut, 2003, character #11; certain taxa scored from character 24 of Smith et al 2007 supplementary info): (0) confluent with anterior rim of maxillary body and gently sloping posterodorsally; (1) offset from anterior rim of maxillary body, with anterior projection of maxillary body shorter than high; (2) offset from anterior rim of maxillary body, with anterior projection of maxillary body as long as high or longer
24. **Nasal process of maxilla, dorsal ramus (ascending ramus of maxilla)** (Turner et al #240, modified from Gauthier, 1986, Cracraft 1986, Chiappe 1996, Clarke and Norell 2002): (0) prominent, exposed laterally and medially; (1) weakly developed, lacking lateral exposure and only slight medial exposure
25. **Anterior margin of maxillary antorbital fossa** (Rauhut, 2003, character #13): (0) rounded or pointed; (1) squared
26. **Dorsal border of the internal antorbital fenestra, lateral view** (Turner et al 2007 #242): (0) formed by lacrimal and maxilla; (1) formed by nasal and lacrimal
27. **Dorsal border of the antorbital fossa, lateral view** (Turner et al 2007 #243): (0) formed by lacrimal and maxilla; (1) formed by nasal and lacrimal; (2) formed by maxilla, premaxilla and lacrimal
28. **In lateral view, lateral lamina of the ventral ramus of nasal process of maxilla** (Turner et al 2007 #244): (0) present, large broad exposure; (1) present, reduced to small triangular exposure
29. **Maxillary antorbital fossa in front of the internal antorbital fenestra** (Rauhut, 2003, character #14; certain taxa scored from character 26 of Smith et al 2007 supplementary info; originally in Sereno et al 1996): (0) 40% or less of the length of the external antorbital fenestra; (1) more than 40% of the length of the external antorbital fenestra
30. **Horizontal ridge on the lateral surface of maxilla at the ventral border of the antorbital fossa** (Rauhut, 2003, character #15; certain taxa scored from character 28 of Smith et al 2007 supplementary info; originally in Rowe and Gauthier 1986): (0) absent; (1) present
31. **Constriction between articulated premaxillae and maxillae** (Rauhut, 2003, character #8; certain taxa scored from character 21 of Smith et al 2007 supplementary info): (0) absent; (1) present
32. **Subnarial gap between maxilla and premaxilla at the alveolar margin** (Rauhut, 2003, character #9; certain taxa scored from character 22 of Smith et al 2007 supplementary info; also in Tykoski 2005): (0) absent; (1) present
33. **Nasals** (certain taxa scored from character 40 of Smith et al 2007 supplementary info): (0) unfused; (1) fused
34. **Dorsal surface of the nasals** (Rauhut, 2003, character #18): (0) smooth; (1) rugose
35. **Pneumatic foramen in the nasals** (Rauhut, 2003, character #19; certain taxa scored from character 38 of Smith et al 2007 supplementary info): (0) absent; (1) present
36. **Narial region (particularly anterior end of the nasals)** (Kirkland et al, character #31): (0) apneumatic or poorly pneumatized; (1) with extensive pneumatic fossae, especially along posterodorsal rim of fossa

37. **Dorsal extent of antorbital fossa** (Rauhut, 2003, character #20; originally Sereno et al 1994; certain taxa scored from character 39 of Smith et al 2007 supplementary info): (0) dorsal rim of antorbital fossa below nasomaxillary suture or formed by this suture; (1) antorbital fossa extending onto the lateroventral side of the nasals
38. **Shape of nasals** (Rauhut, 2003, character #21): (0) expanding posteriorly; (1) of subequal width throughout their length
39. **Pronounced lateral rims of the nasals, sometimes bearing lateral cranial crests** (Rauhut, 2003, character #22): (0) absent; (1) present
40. **External nares** (Rauhut, 2003, character #7): (0) facing laterally; (1) facing strongly anterolaterally
41. **Jugal pneumatic recess in posteroventral corner of antorbital fossa** (Kirkland et al, character #34, also Rauhut, 2003, character #26 (with states reversed): certain taxa scored from character 47 of Smith et al 2007 supplementary info; originally in Sereno et al 1996): (0) present; (1) absent
42. **Medial jugal foramen** (Kirkland et al, character #35; certain taxa scored from character 48 of Smith et al 2007 supplementary info): (0) present on medial surface ventral to postorbital bar; (1) absent
43. **Sublacrimal part of jugal** (Rauhut, 2003, character #23; certain taxa scored from character 46 of Smith et al 2007 supplementary info): (0) tapering; (1) bluntly squared anteriorly; (2) expanded
44. **Anterior end of jugal** (Rauhut, 2003, character #24): (0) posterior to internal antorbital fenestra, but reaching its posterior rim; (1) excluded from the internal antorbital fenestra; (2) expressed at the rim of the internal antorbital fenestra and with a distinct process that extends anteriorly underneath it
45. **Jugal antorbital fossa** (Rauhut, 2003, character #25; originally in Holtz 1994; certain taxa scored from character 50 of Smith et al 2007 supplementary info with states reversed): (0) absent or developed as a slight depression; (1) large, crescentic depression on the anterior end of the jugal
46. **Jugal** (Rauhut, 2003, character #27): (0) broad, plate-like; (1) very slender, rod-like
47. **Jugal** (Kirkland et al, character #33): (0) tall beneath lower temporal fenestra, twice or more as tall dorsoventrally as it is wide transversely; (1) rod-like
48. **Jugal and postorbital** (Kirkland et al, character #32): (0) contribute equally to postorbital bar; (1) ascending process of jugal reduced and descending process of postorbital ventrally elongate
49. **Jugal and quadratojugal** (Kirkland et al, character #37): (0) separate; (1) fused and not distinguishable from one another
50. **Quadratojugal** (Kirkland et al, character #36; also Rauhut, 2003, character #47; certain taxa scored from character 84 of Smith et al 2007 supplementary info): (0) hook-shaped, without posterior process; (1) with broad, short posterior process that wraps around the lateroventral edge of the quadrate
51. **(ordered) Supraorbital crests on lacrimal in adult individuals** (Kirkland et al, 2005 #38; also Rauhut, 2003 #32; certain taxa scored from character 52 of Smith et al 2007 supplementary info): (0) absent; (1) dorsal crest above orbit; (2) lateral expansion anterior and dorsal to orbit
52. **Enlarged foramen or foramina opening laterally at the angle of the lacrimal** (Kirkland et al, character #39; also Rauhut, 2003, character #28; originally in Molnar et al 1990; certain taxa scored from character 51 of Smith et al 2007 supplementary info): (0) absent; (1) present
53. **Height of the lacrimal** (Rauhut, 2003, character #29): (0) significantly less than height of the orbit, and usually fails to reach the ventral margin of the orbit; (1) as high as the orbit, and contacts jugal at the level of the ventral margin of orbit

54. **Lacrimal posterodorsal process** (Kirkland et al, 2003 #40; reductive coding by JNC 2008-09-03; certain taxa scored from character 53 of Smith et al 2007 supplementary info): (0) absent; (1) present
55. **Morphology of posterodorsal prcess of lacrimal** (Kirkland et al, 2003 #40; state added by Senter, 2007, #40): (0) Lacrimal T shaped; (1) anterodorsal process much longer than posterior process; (2) posterodorsal process subvertical
56. **Passage of the nasolacrimal duct** (Rauhut, 2003, character #30): (0) leading through the body of the ventral process of the lacrimal; (1) ventral process of lacrimal not pierced, lateral side depressed below the level of the surrounding bones, and nasolacrimal duct passes lateral to the process
57. **Ventral ramus of lacrimal** (Smith et al 2007 #59): (0) broadly triangular, articular end nearly twice as wide a-p as lacrimal body at lacrimal angle; (1) bar- or strut-like, roughly same width a-p throughout ventral ramus
58. **Prefrontal;** (0) absent; (1) present
59. **Prefrontal** (Rauhut, 2003, character #34; also Kirkland et al, character #41; certain taxa scored from character 61 of Smith et al 2007 supplementary info, state 2 added and state (3) recoded as prefrontal absent): (0) exposed dorsally on the anterior rim of the orbit in lateral view and wih a slender ventral process along the medioposterior rim of the lacrimal; (1) excluded from the anterior rim of the orbit in lateral view, being displaced posteriorly and/or medially, ventral process absent
60. **Configuration of lacrimal and frontal** (Rauhut, 2003, character #35; certain taxa scored from character 54 of Smith et al 2007 supplementary info): (0) lacrimal separated from frontal by prefrontal; (1) lacrimal contacts frontal
61. **Frontals** (Kirkland et al, character #42; also Rauhut, 2003, character #36; certain taxa scored from character 62 of Smith et al 2007 supplementary info with states reversed): (0) narrow anteriorly as a wedge between nasals; (1) end abruptly anteriorly, suture with nasal transversely oriented
62. **Frontal supratemporal fossa** (Turner et al 2007, #245): (0) limited extension of supratemporal fossa onto frontal; (1) supratemporal fossa covers most of frontal process of the postorbital and extends anteriorly onto the dorsal surface of the frontal
63. **Anterior emargination of supratemporal fossa on frontal** (Kirkland et al, character #43): (0) straight or slightly curved; (1) strongly sinusoidal and reaching onto postorbital process
64. **Frontal postorbital process (dorsal view):** (Kirkland et al, character #44): (0) smooth transition from orbital margin; (1) sharply demarcated from orbital margin
65. **Frontal edge** (Kirkland et al, character #45): (0) smooth in region of lacrimal suture; (1) edge notched
66. **Postorbital in lateral view** (Kirkland et al, character #4; certain taxa scored from character 70 of Smith et al 2007 supplementary info): (0) with straight anterior (frontal) process; (1) frontal process curves anterodorsally and dorsal border of temporal bar is dorsally concave
67. **Postorbital bar** (Kirkland et al, character #5): (0) parallels quadrate, lower temporal fenestra rectangular in shape; (1) jugal and postorbital approach or contact quadratojugal to constrict lower temporal fenesta
68. **Contact between lacrimal and postorbital** (Rauhut, 2003, character #39; originally in Sampson et al 1998; certain taxa scored from character 55 of Smith et al 2007 supplementary info): (0) absent; (1) present
69. **Cross-section of the ventral process of the postorbital** (Rauhut, 2003, character #41; originally in Sereno et 1994, 1996; certain taxa scored from character 71 of Smith et al 2007 supplementary info): (0) triangular; (1) U-shaped
70. **Jugal process of the postorbital** (Rauhut, 2003 #40; also Kirkland et al, 2005 #3 (with states reversed): certain taxa scored from character #69 of Smith et al 2007 supplementary info): (0)

ventrally directed and tapering; (1) with a small anterior spur indicating the lower delimitation of the eyeball

71. **Orbit** (Kirkland et al, character #2): (0) round in lateral or dorsolateral view; (1) dorsoventrally elongate
72. **Parietals** (Kirkland et al, character #47): (0) separate; (1) fused
73. **Parietal supratemporal fenestra** (Rauhut, 2003, character #43; certain taxa scored from character 75 of Smith et al 2007 supplementary info and added state (2): originally in Molnar et al 1990; State (0) of this character the same as state (0) of character 45 in Turner et al 2007 supplementary information, but states (1) and (2) of that character are not comparable): (0) separated by a horizontal plate formed by the parietals; (1) contact each other posteriorly, but separated anteriorly by an anteriorly widening triangular plate formed by the parietals; (2) confluent over parietals, parietals form a sagittal crest
74. **(ordered) Sagittal crest** (Kirkland et al, character #46): (0) dorsal surface of parietals smooth with no sagittal crest; (1) parietals dorsally convex with very low sagittal crest along midline; (2) dorsally convex with well-developed sagittal crest
75. **Posteriorly placed, knob-like dorsal projection of the parietals** (Rauhut, 2003, character #42; originally in Coria and Currie 2002; certain taxa scored from character 77 of Smith et al 2007 supplementary info): (0) absent; (1) present
76. **Descending process of squamosal (2)** (Kirkland et al, character #49; also Rauhut, 2003, character #46; certain taxa scored from character 82 of Smith et al 2007 supplementary info, with state (0) and (2) coded as (1) and state (1) coded as (0)): (0) contacts quadratojugal; (1) does not contact quadratojugal
77. **Quadratojugal process of the squamosal** (Rauhut, 2003, character #45; certain taxa scored from character 81 of Smith et al 2007 supplementary info): (0) tapering; (1) broad, and usually somewhat expanded
78. **Posterolateral shelf on squamosal overhanging quadrate head** (Kirkland et al, character #50; certain taxa scored from character 80 of Smith et al 2007 supplementary info): (0) absent; (1) present
79. **Descending process of squamosal** (Kirkland et al, character #48): (0) parallels quadrate shaft; (1) nearly perpendicular to quadrate shaft
80. **Supratemporal fenestra** (Kirkland et al, character #216; certain taxa scored from character 79 of Smith et al 2007 supplementary info): (0) bounded laterally and posteriorly by the squamosal; (1) supratemporal fenestra extended as a fossa on to the dorsal surface of the squamosal
81. **Quadrate head** (Kirkland et al, character #213): (0) covered by squamosal in lateral view; (1) quadrate cotyle of squamosal open laterally exposing quadrate head
82. **Quadrate** (Kirkland et al, 2005 #53; also Rauhut, 2003 #48; certain taxa scored from character 87 of Smith et al 2007 supplementary info): (0) solid; (1) hollow
83. **Mandibular joint** (Rauhut, 2003 #51; also Kirkland et al, 2005 #52 (with state (1) recoded as state (2)): (0) approximately straight below quadrate head; (1) significantly posterior to quadrate head; (2) significantly anterior to quadrate head
84. **Dorsal end of the quadrate** (Rauhut, 2003, character #50; also Kirkland et al, character #51): (0) with a single head that fits into a slot on the ventral side of the squamosal; (1) double-headed, medial head contacts the braincase
85. **Quadrate foramen** (Reductive coding of Rauhut 2003 #49): (0) absent; (1) present
86. **Quadrate foramen** (Rauhut, 2003, character #49; also scored with reference to Kirkland et al, 2005 #55 with states reversed): (0) developed as a distinct opening between the quadrate and quadratojugal; (1) almost entirely closed in the quadrate
87. **(ordered) Ectopterygoid** (Rauhut, 2003 #67; character states modified by JNC; certain taxa scored from character 118 of Smith et al 2007 supplementary info): (0) slender, without ventral fossa; (1) expanded, with a ventral depression medially; (2) expanded, with a deep groove

leading into the ectopterygoid body medially; (3) deeply excavated and medial opening constricted into a foramen

88. **Dorsal recess on ectopterygoid** (Kirkland et al, character #61; certain taxa scored from character 117 of Smith et al 2007 supplementary info): (0) absent; (1) present
89. **Ectopterygoid** (Rauhut, 2003, character #66): (0) posterior to palatine; (1) lateral to palatine
90. **Palatine and ectopterygoid** (Kirkland et al, character #63 (after Currie 1995): certain taxa scored from character 116 of Smith et al 2007 supplementary info): (0) separated by pterygoid; (1) contact
91. **Contact between pterygoid and palatine** (Rauhut 2003, character #68; originally in Ostrom, 1969; certain taxa scored from character 119 of Smith et al 2007 supplementary info): (0) continuous; (1) discontinuous in the mid-region, resulting in a subsidiary palatal fenestra
92. **Flange of pterygoid** (Kirkland et al, character #62): (0) well developed; (1) reduced in size or absent
93. **(ordered) Shape of palatine in ventral view** (Rauhut, 2003, character #65; also Kirkland et al, character #64 (with (0) recoded as state (1) and state (1) recoded as state (2)); originally in Harris, 1998; certain taxa scored from character 114 of Smith et al 2007 supplementary info): (0) plate-like trapezoidal or subrectangular; (1) tetraradiate; (2) jugal process strongly reduced or absent
94. **Suborbital fenestra** (Kirkland et al, character #65): (0) similar in length to orbit; (1) reduced in size or absent
95. **Infratemporal fenestra** (Rauhut, 2003, character #38; certain taxa scored from character #4 of Smith et al 2007 supplementary info): (0) smaller than or subequal in size to orbit; (1) strongly enlarged, more than 1.5 times the size of the orbit
96. **Postorbital part of the skull roof** (Rauhut, 2003, character #44): (0) as high as orbital region; (1) deflected ventrally in adult individuals
97. **Preorbital region of the skull in post-hatchling individuals** (Rauhut, 2003, character #71): (0) elongate, nasals considerably longer than frontals, maxilla at least twice the length of the premaxilla; (1) shortened, nasals subequal in length to frontals or shorter, maxillary length less than twice the length of the premaxillary body
98. **Basipterygoid processes** (Kirkland et al, 2005 #13): (0) well-developed, extending as a distinct process from the base of the basisphenoid; (1) abbreviated or absent
99. **Basipterygoid processes well developed and** (Rauhut 2003 #58. State (2) removed and recoded in character #98 as state (1) (basipterygoid processes abbreviated or absent); State (2) added by JNC 2008-08-09): (0) anteroposteriorly short and finger-like (approximately as long as wide): (1) longer than wide; (2) significantly elongated and tapering
100. **Basipterygoid processes** (Kirkland et al, 2005 #12): (0) ventrally or anteroventrally projecting; (1) lateroventrally projecting; (2) caudally projecting
101. **Basipterygoid processes** (Kirkland et al, 2005 #14): (0) solid; (1) hollow
102. **Basipterygoid recesses on dorsolateral surfaces of basipterygoid processes** (Kirkland et al, character #15): (0) absent; (1) present
103. **Basisphenoid recess** (Rauhut, 2003, character #57; certain taxa scored from character 104 of Smith et al 2007 supplementary info, states (1) and (2) recoded as (1) and coded for character 104 as (0) and (1) respectively): (0) absent or poorly developed; (1) deep and well-developed
104. **Basisphenoid recess position** (Kirkland et al, character #9 (with state (2) removed and coded as (0) for character #57 of Rauhut, 2003)): (0) between basisphenoid and basioccipital; (1) entirely within basisphenoid
105. **Posterior opening of basisphenoid recess** (Kirkland et al, character #10; certain taxa scored from character 105 of Smith et al 2007 supplementary info): (0) single; (1) divided into two small, circular foramina by a thin bar of bone
106. **Basisphenoid between basal tubera and basipterygoid processes** (Rauhut, 2003, character #56; certain taxa scored from character 103 of Smith et al 2007 supplementary info): (0)

approximately as wide as long, or wider; (1) significantly elongated, at least 1.5 times longer than wide

107. **Basisphenoid in lateral view:** (0) oriented subhorizontally; (1) anterior portion located much more ventrally than posterior portion, recess visible in posterior view
108. **Base of cultriform process** (Kirkland et al, character #11; also Rauhut 2003 #62): (0) not highly pneumatised; (1) expanded and pneumatic (parasphenoid bulba)
109. **Exits of CN X-XII** (Kirkland et al, character #19): (0) flush with surface of exoccipital; (1) located together in a bowl-like basisphenoid depression
110. **Exits of CN X and XI** (Rauhut 2003, character #60): (0) laterally through the jugular foramen; (1) posteriorly through a foramen (metotic foramen) lateral to the exit of cranial nerve XII and the occipital condyle
111. **Paroccipital process** (Kirkland et al, character #57; certain taxa scored from character 92 of Smith et al 2007 supplementary info): (0) elongate and slender, with dorsal and ventral edges nearly parallel; (1) short, deep with convex distal end
112. **Paroccipital process*2** (Kirkland et al, character #58; also Rauhut, 2003, character #52. State (2) of Rauhut recoded as state (1) of Kirkland et al 2005; certain taxa scored from character 90 of Smith et al 2007 supplementary info): (0) straight, projects laterally or posterolaterally; (1) distal end curves ventrally, pendant
113. **Paroccipital process*3** (Kirkland et al, character #59; certain taxa scored from character 93 of Smith et al 2007 supplementary info; originally in Currie 1995): (0) with straight dorsal edge; (1) distal end twists rostrally, distal ends of the processes oriented transversely rather than vertically
114. **Base of paroccipital processes** (Rauhut, 2003, character #53): (0) solid; (1) hollowed anteriorly by diverticulum of posterior tympanic recess
115. **Ventral rim of the basis of the paroccipital processes** (Rauhut, 2003, character #54; certain taxa scored from character 91 of Smith et al 2007 supplementary info): (0) above or level with the dorsal border of the occipital condyle; (1) situated at mid-height of occipital condyle or lower
116. **Foramen magnum** (Kirkland et al, character #55): (0) subcircular, slightly wider than tall; (1) oval, taller than wide
117. **Occipital condyle** (Kirkland et al, character #56): (0) without constricted neck; (1) subspherical with constricted neck
118. **Basal tubera** (Rauhut, 2003, character #55; certain taxa scored from character 100 of Smith et al 2007 supplementary info): (0) equally formed by basioccipital and basisphenoid and not subdivided; (1) subdivided by a lateral longitudinal groove into a medial part entriely formed by the basioccipital, and a lateral part, entirely formed by the basisphenoid
119. **Basal tubera** (Kirkland et al, character #222; originally in Holtz 200; certain taxa scored from character 102 of Smith et al 2007 supplementary info): (0) set far apart, level with or beyond lateral edge of occipital condyle and/or foramen magnum (may be connected by a web of bone or separated by a large notch): (1) tubera small, directly below condyle and foramen magnum, and separated by a narrow notch
120. **Subcondylar recess** (Kirkland et al, character #223; wording changed by JNC 2008-07-07): (0) absent; (1) present in basioccipital/exoccipital lateral and ventral to occipital condyle
121. **Exit of mid-cerebral vein** (Rauhut, 2003, character #61): (0) included in trigeminal foramen; (1) vein exits braincase through a separate foramen anterodorsal to the trigeminal foramen
122. **Brain proportions** (Rauhut, 2003, character #64): (0) forebrain small and narrow; (1) forebrain significantly enlarged and triangular
123. **Anterior tympanic recess in the braincase** (Rauhut, 2003, character #59; Originally in Makovicky and Sues 1998; certain taxa scored from character 107 of Smith et al 2007 supplementary info): (0) absent; (1) present

124. **(ordered) Depression for pneumatic recess on prootic** (Kirkland et al, character #16): (0) absent; (1) present as dorsally open fossa on prootic/opisthotic; (2) present as deep, posterolaterally directed concavity
125. **Crista interfenestralis** (Kirkland et al, character #7): (0) confluent with lateral surface of prootic and opisthotic; (1) distinctly depressed within middle ear opening
126. **(ordered) Dorsal tympanic recess (dorsal to crista interfenestralis)** (Kirkland et al, character #17; edited by JNC 2008-07-07): (0) absent; (1) small pocket present; (2) extensive with indirect pneumatisation
127. **(ordered) Caudal (posterior) tympanic recess** (Kirkland et al, character #18; certain taxa scored from character 94 of Smith et al 2007 supplementary info): (0) absent; (1) present as opening on anterior surface of paroccipital process; (2) extends into opisthotic posterodorsal to fenestra ovalis, confluent with this fenestra
128. **Otosphenoidal crest** (Kirkland et al, character #6): (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
129. **Subotic recess (pneumatic fossa ventral to fenestra ovalis)** (Kirkland et al, character #8): (0) absent; (1) present
130. **Depression (possibly pneumatic) on ventral surface of postorbital process of laterosphenoid** (Kirkland et al, character #221): (0) absent; (1) present
131. **(ordered) Symphyseal region of dentary** (Kirkland et al, 2005 #66; SEE also Rauhut, 2003 #76 (state (0) kept as (0), state (1) recoded as state (3), pending further research)): (0) Broad and straight, paralleling lateral margin; (1) medially recurved slightly; (2) strongly recurved medially
132. **Dentary symphyseal region in medial view** (Kirkland et al, character #67): (0) in line with main part of buccal edge; (1) end downturned
133. **(ordered) Posterior end of dentary** (Kirkland et al, 2005 #69; also Rauhut, 2003 #77 (recoded with state (0) as state (2), with state (1) as state (3) pending further research)): (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
134. **Jaws** (Kirkland et al, character #212; originally in Perez-Moreno et al 1994; certain taxa scored from character 126 of Smith et al 2007 supplementary info): (0) occlude for their full length; (1) diverge rostrally due to kink and downward deflection in dentary buccal margin
135. **Labial face of dentary** (Kirkland et al, character #70): (0) flat; (1) with lateral ridge and inset tooth row
136. **(ordered) Nutrient foramina on external surface of dentary** (Kirkland et al, character #72; State (2) added by JNC 2008-07-29; this character not ordered because state (1) is not necessarily nested within state (2)): (0) superficial; (1) descend strongly posteriorly within a deep groove; (2) descend posteriorly within triangular groove, caudal end of this groove is dorsoventrally expanded
137. **Dentary shape** (Kirkland et al, character #71): (0) subtriangular in lateral view; (1) with subparallel dorsal and ventral edges; (2) high triangular in lateral view (as in *Citipati*)
138. **Ventral surface of dentary** (Kirkland et al, character #224): (0) straight or nearly straight; (1) descends strongly posteriorly
139. **Pronounced coronoid eminence on the surangular** (Rauhut, 2003 #72; also Kirland et al, 2005 #68): (0) absent; (1) present (Rauhut, 2003 #72)
140. **Foramen in lateral surface of surangular rostral to mandibular articulation** (Kirkland et al, character #75): (0) absent; (1) present
141. **Laterally inclined flange along dorsal edge of surangular for articulation with lateral process of lateral quadrate condyle** (Kirkland et al, character #209; certain taxa scored from

character 134 of Smith et al 2007 supplementary info; originally in Holtz 1998): (0) absent; (1) present

142. **Anterior portion of the surangular** (Rauhut, 2003, character #75; originally in Gauthier 1986; certain taxa scored from character 132 of Smith et al 2007 supplementary info): (0) less than half the height of the mandible above the mandibular fenestra; (1) more than half the height of the mandible at the level of the mandibular fenestra
143. **Retroarticular process of the mandible** (Rauhut, 2003, character #73; also Kirkland et al, character #79 (with states reversed): originally in Sereno et al 1996, also Harris 1998; certain taxa scored from character 139 of Smith et al 2007 supplementary info): (0) narrow, rod-like; (1) broadened, with groove posteriorly for the attachment of the m. depressor mandibulae
144. **Attachment of the m. depressor mandibulae on retroarcticular process of mandible** (Rauhut, 2003, character #74; originally in Sereno et al 1996; certain taxa scored from character 140 of Smith et al 2007 supplementary info): (0) facing dorsally; (1) facing posterodorsally
145. **Retroarticular process** (Kirkland et al, character #219): (0) points caudally; (1) curves gently dorsocaudally
146. **Articular** (Kirkland et al, character #78): (0) without elongate, slender medial, posteromedial, or mediodorsal process from retroarticular process; (1) with process
147. **Angular** (Kirkland et al, character #208; certain taxa scored from character 137 of Smith et al 2007 supplementary info): (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
148. **(ordered) Coronoid ossification** (Kirkland et al, character #77; also Rauhut, 2003, character #80 (with state (1) recoded as state (2), with state (0) coded as (3) pending further research)): (0) large; (1) thin splint; (2) absent
149. **Splenial** (Kirkland et al, character #76; certain taxa scored from character 129 of Smith et al 2007 supplementary info with states reversed): (0) not widely exposed on lateral surface of mandible; (1) exposed as a broad triangle between dentary and angular on lateral surface of mandible
150. **Foramen in the ventral part of the splenial (mylohyal foramen)** (Rauhut, 2003, character #78; reductive coding by JNC; certain taxa scored from character 130 of Smith et al 2007 supplementary info): (0) absent; (1) present
151. **Form of mylohyal foramen;** (0) completely enclosed in the splenial; (1) opened anteroventrally
152. **Posterior end of splenial** (Rauhut, 2003, character #79; certain taxa scored from character 131 of Smith et al 2007 supplementary info; originally in Sereno et al 1996): (0) straight; (1) forked
153. **Mandibular articulation surface** (Kirkland et al, character #80): (0) as long as distal end of quadrate; (1) twice or more as long as quadrate surface, allowing anteroposterior movement of mandible
154. **Mandibular foramen** (Gohlich and Chiappe 2006 #71): (0) large; (1) absent or reduced
155. **Shape of mandibular foramen** (Kirkland et al, character #73): (0) oval; (1) subdivided by a spinous rostral process of the surangular
156. **Internal mandibular fenestra** (Kirkland et al, character #74): (0) small and slit-like; (1) large and rounded
157. **Palatal teeth** (Rauhut, 2003, character #69; certain taxa scored from character 120 of Smith et al 2007 supplementary info): (0) present; (1) absent
158. **Premaxillary teeth** (Rauhut, 2003, character #81; also Kirkland et al, character #81): (0) present; (1) absent

159. **Number of premaxillary teeth** (Rauhut, 2003, character #5; certain taxa scored from character 8 of Smith et al 2007 supplementary info): (0) three; (1) four; (2) five; (3) more than five
160. **First premaxillary tooth size** (Turner et al 2007, #251; also in Currie and Varrichio, 2004 #42; and in Currie, 1995): (0) slightly smaller or the same size as 2 and 3; (1) much smaller than 2 and 3; (2) much larger than 2 and 3
161. **Second premaxillary tooth** (Kirkland et al, #82): (0) approximately equivalent in size to other premaxillary teeth; (1) markedly larger than third and fourth premaxillary teeth
162. **Serrations on premaxillary teeth** (Rauhut, 2003, character #84; certain taxa scored from character 17 of Smith et al 2007 supplementary info): (0) present; (1) absent
163. **In cross section, premaxillary tooth crowns** (Kirkland et al, character #91; certain taxa scored from character 18 of Smith et al 2007 supplementary info; originally in Bakker, 1988): (0) sub-oval to sub-circular; (1) asymmetrical (D-shaped in cross section) with flat lingual surface
164. **Maxillary teeth** (Kirkland et al, 2005 #83): (0) present; (1) absent (Kirkland et al, 2005 #83)
165. **(ordered) Maxillary and dentary teeth** (Kirkland et al, character #84; also Rauhut, 2003, character #82 (with (0) coded as (0), (1) coded as (2)): certain taxa scored from character 36 of Smith et al 2007 supplementary info; originally in Chiappe 1996): (0) serrated; (1) some without serrations anteriorly (except at base in S. mongoliensis): (2) all without serrations
166. **Serration denticles** (Kirkland et al, 2005 #86): (0) large; (1) small
167. **Serrations** (Kirkland et al, 2005 #87): (0) simple, denticles convex; (1) distal and often mesial edges of teeth with large, hooked denticles that point toward the tip of the crown
168. **Maxillary tooth row** (Rauhut, 2003, character #70; certain taxa scored from character 3 of Smith et al 2007 supplementary info): (0) extends posteriorly to approximately half the length of the orbit; (1) ends at the anterior rim of the orbit; (2) completely antorbital, tooth row ends anterior to the vertical strut of the lacrimal
169. **Constriction between tooth crown and root** (Rauhut, 2003, character #87; also Kirkland et al, character #88 (with states reversed)): (0) absent; (1) present
170. **(ordered) Dentary** (Kirkland et al, character #217): (0) fully toothed; (1) only teeth rostrally; (2) edentulous
171. **Dentary teeth** (Kirkland et al, 2005 #231; also Rauhut, 2003 #83): (0) homodont; (1) increasing in size anteriorly, becoming more conical in shape; (2) Decreasing in size anteriorly, becoming more densely packed
172. **Roots of dentary and maxillary teeth** (Kirkland et al, character #228): (0) mediolaterally compressed; (1) circular in cross-section
173. **Maxillary teeth** (State (3) added from Zhang et al 2008, who depict this condition for some troodontids and detail state (2) as the condition in birds): (0) mediolaterally flattened and recurved; (1) lanceolate and subsymmetrical (as in therizinosaurs): (2) simple, conical, incisive crowns; (3) labiolingually flattened and recurved, with crown in middle of tooth row less than twice as high as the basal mesiolateral width
174. **Maxillary tooth implantation:** (0) separate alveoli; (1) set in an open groove
175. **Dentary tooth implantation** (Turner et al 2007 #85; originally in Currie 1987): (0) separate alveoli; (1) set in an open groove
176. **Dentary teeth** (Kirkland et al, character #230): (0) mediolaterally flattened and recurved; (1) lanceolate and subsymmetrical
177. **Dentary tooth size and number** (Kirkland et al, character #85; certain taxa scored from character 127 of Smith et al 2007 supplementary info): (0) large, fewer than 25 in dentary; (1) moderate number of small teeth (25-30 in dentary): (2) relatively small and numerous (more than 30 in dentary)
178. **Dentaries** (Kirkland et al, character #90): (0) lack interdental plates; (1) with interdental plates medially between teeth

179. **Axial neural spine** (Rauhut 2003, character #93. Kirkland et al, character #94; certain taxa scored from character 145 of Smith et al 2007 supplementary info): (0) flared transversely and sheet-like; (1) compressed mediolaterally, anteroposteriorly reduced, and rodlike
180. **(ordered) Epipophyses on axis** (Rauhut 2003, character #92. Kirkland et al, character #93 (with state (1) recoded as (2)): (0) absent; (1) present as small ridges; (2) strongly pronounced (overhanging the zygapophyses)
181. **Pleurocoel in axis** (Rauhut, 2003, character #91; certain taxa scored from character 142 of Smith et al 2007 supplementary info): (0) absent; (1) present
182. **(ordered) Epipophyses in anterior cervical vertebrae** (Rauhut, 2003 #102, also Kirkland et al 2005, #25, with Kirkland state (0) =Rauhut (2) and Kirkland state (1) = rauhut (1): Originally in Gauthier 1986; certain taxa scored from character 159 of Smith et al 2007 supplementary info): (0) absent or poorly developed; (1) well-developed, proximal to postzygapophyseal facets; (2) pronounced, strongly overhanging the postzygapophyses
183. **Postzygapophyses of cervical vertebrae 2-4**: (0) well-separated, or connected only at the base (JNC 2008-09-17 personal observation): (1) medially connected along their length by a web of bone that is dorsally concave for attachment of the interspinous ligaments
184. **Anterior articular facet of anterior cervical vertebrae** (Rauhut, 2003, character #101; also Kirkland et al, character #98, with state (0) recoded as (0), and state (1) recoded as (2); certain taxa scored from character 154 of Smith et al 2007 supplementary info): (0) approximately as high as wide or higher; (1) significantly wider than high; (2) wider than high and higher laterally than medially (kidney-shaped), with neural canal emarginating dorsal aspect
185. **Cervical vertebral centra** (Rauhut, 2003, character #95; also Kirkland et al, character #101; certain taxa scored from character 151 of Smith et al 2007 supplementary info; state (2) added from Turner et al 2007): (0) amphi- to platycoelus; (1) opisthocoelus; (2) heterocoelus
186. **Anterior cervical centra** (Kirkland et al, character #96; certain taxa scored from character 155 of Smith et al 2007 supplementary info): (0) level with or shorter than posterior extent of neural arch; (1) centra extending beyond posterior limit of neural arch
187. **Carotid process on posterior cervical vertebrae** (Kirkland et al, character #97): (0) absent; (1) present
188. **Cervical neural spines** (Kirkland et al, character #99; certain taxa scored from character 164 of Smith et al 2007 supplementary info with state (2) added): (0) anteroposteriorly long; (1) anteroposteriorly short and centered on neural arch, giving arch an "X" shape in dorsal view; (2) extremely short anteroposteriorly, less than 1/3 length of neural arch
189. **Number of cervical vertebrae** (Kirkland et al, character #92): (0) 10; (1) 12 or more
190. **Pleurocoels in cervical vertebrae** (Rauhut, 2003, character #88; certain taxa scored from character 147 of Smith et al 2007 supplementary info): (0) absent; (1) present
191. **Number of pleurocoels in cervicals** (Rauhut, 2003, character #89; also Kirkland et al, character #100 (with states reversed): certain taxa scored from character 148 of Smith et al 2007 supplementary info): (0) two, arranged horizontally; (1) one
192. **Pleurocoels developed as** (Rauhut, 2003, character #90; certain taxa scored from character 149 of Smith et al 2007 supplementary info): (0) deep depressions; (1) foramina
193. **Interior pneumatic spaces in cervicals** (Rauhut, 2003, character #96; certain taxa scored from character 152 of Smith et al 2007 supplementary info): (0) Structure camerate (few chambers): (1) Structure camellate (many chambers separated by delicate lamellae)
194. **Ventral keel in anterior cervicals** (Rauhut, 2003, character #97): (0) present; (1) absent
195. **Broad ridge from the diapophyses to the ventral rim of the posterior end of the vertebral centra in cervical vertebrae** (Rauhut, 2003, character #98): (0) absent; (1) present
196. **Prezygapophyses in anterior cervicals** (Rauhut, 2003, character #99; originally in Makovicky 1995; certain taxa scored from character 156 of Smith et al 2007 supplementary info): (0) transverse distance between prezygapophyses less than width of neural canal; (1) prezygapophyses situated lateral to the neural canal

197. **Prezygapophyses in anterior postaxial cervicals** (Rauhut, 2003, character #100; Originally in Gauthier, 1986; certain taxa scored from character 157 of Smith et al 2007 supplementary info): (0) straight; (1) anteroposteriorly convex, flexed ventrally anteriorly
198. **Hypapophyses in anterior dorsals** (Rauhut, 2003, character #107; also Kirkland et al, character #102): (0) absent or poorly developed; (1) pronounced
199. **Hyposphene-hypantrum articulation in dorsal vertebrae** (Rauhut, 2003, character #103; also Kirkland et al, character #104; certain taxa scored from character 173 of Smith et al 2007 supplementary info with state (1) and (2) scored as (1)): (0) absent; (1) present
200. **Postzygapophyses of trunk vertebrae** (Kirkland et al, character #105): (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, hyposphens separated
201. **Neural spines on posterior dorsal vertebrae in lateral view** (Kirkland et al, character #206; also Rauhut, 2003, character #110; Originally in Chen et al 1998; certain taxa scored from character 176 of Smith et al 2007 supplementary info): (0) rectangular or square; (1) anteroposteriorly expanded distally, fan-shaped
202. **Neural spines of dorsal vertebrae in dorsal view** (Kirkland et al, character #108; certain taxa scored from character177 of Smith et al 2007 supplementary info): (0) not expanded distally; (1) expanded laterally in dorsal view to form "spine table"
203. **Scars for interspinous ligaments** (Kirkland et al, character #109; certain taxa scored from character 178 of Smith et al 2007 supplementary info): (0) terminate at apex of neural spine in dorsal vertebrae; (1) terminate below apex of neural spine
204. **Neural spine of posterior dorsals** (Rauhut, 2003, character #109; certain taxa scored from character 175 of Smith et al 2007 supplementary info): (0) broadly rectangular and approximately as d-v high as a-p long; (1) high rectangular, significantly d-v higher than a-p long
205. **Hook-like extension on anterior end of dorsal neural spines in lateral view** (Adopted from Peyer, 2006): (0) absent; (1) present (with associated depression immediately caudal to the projection for spinous ligament attachment)
206. **Parapophyses of posterior trunk vertebrae** (Kirkland et al, character #103; certain taxa scored from character 180 of Smith et al 2007 supplementary info): (0) flush with neural arch; (1) distinctly projected on pedicels
207. **Parapophyses in posteriormost dorsals** (Rauhut 2003, character #111; originally in Makovicky 1995; certain taxa scored from character 179 of Smith et al 2007 supplementary info): (0) on same level as transverse process; (1) distinctly below transverse process
208. **(ordered) Pleurocoels in dorsal vertebrae** (Rauhut, 2003, character #106): (0) absent; (1) present in anterior dorsals ('pectorals'): (2) present in all dorsals
209. **Transverse processes of anterior dorsal vertebrae** (Kirkland et al, character #107): (0) long and thin; (1) short, wide and only slightly inclined
210. **Dorsal centra articular surfaces** (Taken from Longrich and Currie, 2008; originally in Perle et al 1993): (0) amphiplatyan; (1) opisthocoelus
211. **Ventral keel in anterior dorsals** (Rauhut, 2003, character #108; certain taxa scored from character 170 of Smith et al 2007 supplementary info): (0) absent or very poorly developed; (1) pronounced
212. **Shape of dorsal centra in anterior view** (Rauhut, 2003, character #105): (0) subcircular or oval; (1) significantly wider than high; (2) triangular
213. **Posterior dorsal vertebrae** (Rauhut, 2003, character #112): (0) strongly shortened, centra much shorter than high; (1) relatively short, centra approximately as high as long, or only slightly longer; (2) significantly elongated, much longer than high

214. **Number of sacral vertebrae** (Kirland et al, 2005 #110 (state (0) recoded as state (3), state (1) recoded as state (4), state (2) recoded as state (5)): also Rauhut, 2003 #113): (0) two; (1) three; (2) four; (3) five; (4) six; (5) seven; (6) eight; (7) nine
215. **(ordered) Pleurocoels in sacral vertebrae** (Kirkland et al, 2005 #113; also Rauhut, 2003 #115 (state (1) recoded as state (3)): (0) absent; (1) present on anterior sacrals only; (2) present on all sacrals
216. **Ventral surface of posterior sacral centra** (Rauhut, 2003, character #114; Kirkland et al, 2005 #112, after Novas, 1997): (0) gently rounded, convex; (1) flattened ventrally, sometimes with shallow sulcus; (2) centrum strongly constricted transversely, ventral surface keeled
217. **Sacral ribs** (Rauhut, 2003, character #116; Originally in Rowe and Gauthier, 1990; certain taxa scored from character 187 of Smith et al 2007 supplementary info): (0) slender and well-separated; (1) forming a more or less continuous sheet in ventral or dorsal view; (2) very massive and strongly expanded
218. **Sacral vertebrae** (Kirkland et al, character #111): (0) with unfused zygapophyses; (1) with fused zygapophyses forming a sinuous ridge in dorsal view
219. **Last sacral centrum** (Kirkland et al, character #114): (0) with flat posterior articulation surface; (1) convex articulation surface
220. **Ventral surface of posterior sacral centra** (Character modified from Longrich and Currie, 2008 #19; originally from Perle et al 1994, also in Novas 1996): (0) rounded or flat; (1) strong ventral keel
221. **Number of caudal vertebrae** (Kirkland et al, 2005 #121; also Rauhut, 2003 #117 (states (1) and (2) recoded as state (3))): (0) more than 40; (1) 25-40; (2) fewer than 25; (3) tail short and fused into a pygostyle
222. **Caudal vertebrae** (Kirland et al, 2005 #115): (0) with distinct transition point, from shorter centra with long transverse processes proximally to longer centra with small or no transverse processes distally; (1) homogeneous in shape, with no transition point
223. **Caudal vertebral centra** (Scored from Longrich and Currie, 2008 #21; originally from Novas, 1996): (0) amphiplatyan; (1) procoelus
224. **Position of transition point** (Turner, 2007 #116; Rauhut, 2003 #119): (0) distal to the tenth caudal vertebra; (1) between the 7th and 10th caudal vertebrae; (2) proximal to the 7th caudal vertebra
225. **Location of transverse processes of proximal caudals** (Longrich and Currie 2008 #22): (0) centrally positioned on centrum; (1) anteriorly displaced
226. **Shape of anterior caudal centra** (Rauhut, 2003 #127; also Kirkland et al, 2005 #117 (with state (2) recoded as state (1) of Rauhut #121): certain taxa scored from character 190 of Smith et al 2007 supplementary info): (0) oval; (1) subrectangular and box-like; (2) laterally compressed with a ventral keel
227. **Ventral groove in anterior caudals** (Rauhut, 2003 #120): (0) absent; (1) present
228. **Ventral surface of anterior caudals** (Rauhut, 2003 #121; also Kirkland et al, 2005 #117): (0) rounded; (1) with a distinct keel bearing a narrow, shallow groove on its midline
229. **(ordered) Neural spines on distal caudals** (Kirkland et al, character #119): (0) form a low ridge; (1) spine absent; (2) midline sulcus in center of the neural arch
230. **Neural spines of caudal vertebrae** (Kirkland et al, character #118. The anterior spur of Rauhut, 2003 character #125 is the same as an anterior ala; certain taxa scored from character 198 of Smith et al 2007 supplementary info): (0) simple, undivided; (1) separated into anterior and posterior alae throughout much of caudal sequence
231. **Neural spines of mid-caudals** (Rauhut, 2003, character #124; certain taxa scored from character 197 of Smith et al 2007 supplementary info): (0) rod-like and posteriorly inclined; (1) subrectangular and sheet-like; (2) rod-like and vertical
232. **Prezygapophyses of distal caudal vertebrae** (Combination of Kirkland et al, character #120 and Rauhut 2003, character #122. Note state renumbering): (0) between 1/3 and whole centrum

length; (1) with extremely long extensions of the prezygapophyses (up to 10 vertebral segments in some taxa) (state (1) of Rauhut 2003, character #122): (2) strongly reduced as in Archaeopteryx lithographica

233. **Anterior margin of neural spines of anterior mid-caudal vertebrae** (Rauhut, 2003, character #123; certain taxa scored from character 195 of Smith et al 2007 supplementary info): (0) straight; (1) with distinct kink, dorsal part of anterior margin more strongly inclined posteriorly than ventral part
234. **Relative length of distal caudal centra** (Rauhut, 2003, character #126): (0) significantly elongated in relation to centrum height; (1) not elongated in relation to centrum height
235. **Cranial process at base of chevrons** (Rauhut, 2003, character #128; certain taxa scored from character 199 of Smith et al 2007 supplementary info): (0) absent; (1) present
236. **Distal chevrons** (Rauhut, 2003, character #129; certain taxa scored from character #202 of Smith et al 2007 supplementary info): (0) rod-like or L-shaped; (1) skid-like
237. **Mid-caudal chevrons** (Rauhut, 2003, character #130; originally Sereno et al 1996; certain taxa scored from character 201 of Smith et al 2007 supplementary info): (0) rod-like or only slightly expanded ventrally; (1) L-shaped
238. **Proximal end of chevrons of proximal caudals** (Kirkland et al, character #122; certain taxa scored from character 200 of Smith et al 2007 supplementary info): (0) short anteroposteriorly, shaft cylindrical; (1) proximal end elongate anteroposteriorly, flattened and plate-like
239. **(ordered) Distal caudal chevrons** (Kirkland et al, character #123): (0) simple; (1) anteriorly bifurcate; (2) bifurcate at both ends
240. **Long, hair-like cervical ribs:** (0) absent; (1) present
241. **Shaft of cervical ribs** (Kirkland et al, character #124; certain taxa scored from character 167 of Smith et al 2007 supplementary info): (0) slender and longer than vertebra to which they articulate; (1) broad and shorter than vertebra
242. **Ossified uncinate processes** (Kirkland et al, character #125; certain taxa scored from character 203 of Smith et al 2007 supplementary info): (0) absent; (1) present
243. **Lateral gastral segment** (Kirkland et al, character #127): (0) shorter than medial one in each arch; (1) distal segment longer than proximal segment
244. **(ordered) Ossified sternal plates** (Kirkland et al, character #128; certain taxa scored from character 208 of Smith et al 2007 supplementary info): (0) separate in adults; (1) fused; (2) fused with ventral keel
245. **Sternum** (Kirkland et al, character #129): (0) without distinct lateral xiphoid process posterior to costal margin; (1) with lateral xiphoid process
246. **Furcula** (Rauhut, 2003, character #131): (0) absent; (1) present
247. **Hypocleidium on furcula** (Kirkland et al, character #132): (0) absent; (1) present
248. **Articular facet of coracoid on sternum** (conditions may be determined by the articular facet on coracoid in taxa without ossified sternum; Kirkland et al, character #131 (after Xu et al. 1999)): (0) anterolateral or more lateral than anterior; (1) almost anterior
249. **Anterior edge of sternum** (Kirkland et al, character #130): (0) grooved for reception of coracoids; (1) without grooves
250. **Coracoid in lateral view** (Kirkland et al, character #136; also Rauhut, 2003, character #138; Originally Gauthier 1986; certain taxa scored from character 219 of Smith et al 2007 supplementary info): (0) subcircular, with shallow ventral blade; (1) subquadrangular with extensive ventral blade; (2) shallow ventral blade with elongate posteroventral process; (3) strut-like
251. **Posterior edge of coracoid** (Kirkland et al, 2005 #218): (0) not or shallowly indented below glenoid; (1) posterior edge of coracoid deeply notched just ventral to glenoid, glenoid lip everted

252. **Anterior surface of coracoid ventral to glenoid fossa** (Kirkland et al, character #134): (0) unexpanded; (1) expanded, forms triangular subglenoid fossa bounded laterally by coracoid tuber
253. **Coracoid tubercle;** (0) absent; (1) present
254. **Coracoid tubercle form**: (0) anteroposteriorly short, mound-like; (1) anteroposteriorly elongated, ridge-like
255. **Scapula shape** (Rauhut, 2003 #132; certain taxa scored from character 212 of Smith et al 2007 supplementary info): (0) short and broad (ratio length/minimal height of shaft <9): (1) slender and elongate (ratio >10)
256. **Acromion margin of scapula** (Kirkland et al, character #133. Also Rauhut 2003, character #134 (with states reversed): certain taxa scored from character 214 of Smith et al 2007 supplementary info with states reversed): (0) continuous with blade (same as Rauhut 2003, character #134: state (1)): (1) anterior edge laterally everted (same as Rauhut 2003, character #134: state (0))
257. **Flange on supraglenoid buttress on scapula (see Nicholls and Russell, 1985)** (Kirkland et al, character #220): (0) absent; (1) present
258. **Distal end of scapula** (Rauhut, 2003, character #133; certain taxa scored from character 213 of Smith et al 2007 supplementary info; Originally in Gauthier, 1986): (0) expanded; (1) not expanded
259. **Glenoid fossa** (Kirkland et al, character #138; also Rauhut 2003 character #135): (0) faces posteriorly or posterolaterally; (1) faces laterally
260. **Scapula and coracoid** (Kirkland et al, character #135): (0) separate; (1) fused into scapulocoracoid
261. **Scapula and Coracoid 2** (certain taxa scored from character 216 of Smith et al 2007 supplementary info): (0) continuous arc in posterior and anterior views; (1) coracoid inflected medially, scapulocoracoid L shaped in lateral view
262. **Scapula** (Turner et al 2007 #139): (0) longer than humerus; (1) shorter than humerus
263. **Deltopectoral crest** (Kirkland et al, 2005 #140): (0) large and distinct, proximal end of humerus quadrangular in anterior view; (1) less pronounced, forming an arc rather than being quadrangular; (2) very weakly developed, proximal end of humerus with rounded edges; (3) extremely long (as in Shuvuuia and Mononykus): (4) proximal end of humerus extremely broad, triangular in anterior view
264. **Anterior surface of deltopectoral crest** (Turner, 2007 #141; certain taxa scored from character 224 of Smith et al 2007 supplementary info): (0) smooth; (1) with distinct muscle scar near lateral edge along distal end of crest for insertion of biceps muscle
265. **Ratio femur/humerus** (Rauhut, 2003, character #139): (0) more than 2.5; (1) between 1.2 and 2.2; (2) less than (1)
266. **Outline of proximal articular facet of humerus** (Rauhut, 2003, character #140; certain taxa scored from character 221 of Smith et al 2007 supplementary info): (0) broadly oval (more than twice as broad transversely than anteroposteriorly): (1) distinctly rounded, often globular (less than twice as broad anteroposteriorly than transversely)
267. **Internal tuberosity of humerus** (with reference to Chiappe et al 2003, Novas 1996): (0) small and confluent with humeral head; (1) offset from humeral head by distinct notch, often projects proximally above humeral head; (2) hypertrophied but not distinct from humeral head (as in Suchomimus)
268. **Shape of internal tuberosity on humerus in anterior view** (Rauhut, 2003, character #141): (0) triangular, often rounded; (1) rectangular
269. **Humerus in lateral view** (Rauhut, 2003, character #143; originally in Holtz, 1994; certain taxa scored from character 220 of Smith et al 2007 supplementary info): (0) sigmoidal; (1) straight

270. **Ectepicondyle of humerus (lateral epicondyle)**: (0) small, often rectangular and does not form articular surface; (1) large, rounded and forms articular surface
271. **Entepicondyle of humerus (medial epicondyle)** (Kirkland et al, character #225, clarified by JNC): (0) absent or small and tabular; (1) large, projects medially from ulnar condyle as a distinct process and is distally separated from ulnar condyle by a groove
272. **Distal humeral condyles** (Kirkland et al, character #226): (0) primarily developed on distal end of humerus, but may also have some articular surface extending to anterior edge; (1) limited to anterior surface, condylar surfaces not present on distal end
273. **Olecranon process of ulna** (Rauhut, 2003, character #144; also Kirkland et al, character #142; Originally in Novas, 1998; certain taxa scored from character 227 of Smith et al 2007 supplementary info): (0) well-developed; (1) strongly reduced or absent
274. **Proximal surface of ulna** (Kirkland et al, character #144; certain taxa scored from character 228 of Smith et al 2007 supplementary info): (0) single continuous articular facet; (1) divided into two distinct fossae
275. **Distal articular surface of ulna** (Kirkland et al, character #143): (0) flat; (1) convex, semilunate surface
276. **Distal condyle articular surface of ulna** (Longrich and Currie, 2008 #33): (0) unexpanded or spatulate, articular surface limited to distal end; (1) bulbous, trochlear articular surface extends onto dorsal surface of ulna
277. **Radius** (Rauhut, 2003, character #145; certain taxa scored from character #229 of Smith et al 2007 supplementary info): (0) more than half the length of humerus; (1) less than half the length of humerus
278. **Radius and ulna** (Kirkland et al, character #211): (0) well-separated; (1) with distinct adherence or syndesmosis distally
279. **Distal end of radius**: (0) unexpanded; (1) expanded dorsoventrally
280. **Ossified carpals:** (0) absent; (1) present (Personal observation, but may appear in some ceratosaur matrices)
281. **Lateral proximal carpal (ulnare?)** (Kirkland et al, character #145; certain taxa scored from character 231 of Smith et al 2007 supplementary info): (0) quadrangular; (1) triangular in proximal view
282. **"Semilunate" distal carpal** (Modified from Rauhut 2003, character #146): (0) absent (same as state (0) for Rauhut 2003 #146): (1) present (code as (1) for Rauhut 2003 #146: states (1), (2) or (3))
283. **Two distal carpals** (Kirkland et al, character #146; certain taxa scored from character 232 of Smith et al 2007 supplementary info): (0) in contact with metacarpals, one covering the base of Mc I (and perhaps contacting Mc II) , the other covering the base of Mc II; (1) two distal carpals not present, single distal carpal capping Mc I and II
284. **Distal carpals** (Kirkland et al, character #147): (0) not fused to metacarpals; (1) fused to metacarpals, forming carpometacarpus
285. **Ilium** (Rauhut, 2003, character #166): (0) brachyiliac; (1) dolichoiliac
286. **Ventral edge of anterior ala of ilium** (Kirkland et al, character #154; also Rauhut, 2003, character #168 (keeping character state (0) and recoding state (1) as state (3) pending further research): certain taxa scored from character 253 of Smith et al 2007 supplementary info): (0) straight or gently curved; (1) ventral edge hooked anteriorly; (2) very strongly hooked
287. **Preacetabular part of ilium** (Rauhut, 2003, character #169; also Kirkland et al, character #155 (with state (0) recoded as state (1), with state (1) recoded as state (2)): certain taxa scored from character 254 of Smith et al 2007 supplementary info): (0) significantly shorter than postacetabular part; (1) subequal in length to postacetabular part; (2) significantly longer than postacetabular process
288. **Anterior rim of ilium** (Rauhut 2003, character #173. Kirkland et al, character #156.; certain taxa scored from character 256 of Smith et al 2007 supplementary info): (0) gently convex or

straight; (1) distinctly concave dorsally; (2) anterior end strongly curved; (3) pointed at the anterodorsal corner

289. **Preacetabular part of ilium (height)** (Rauhut, 2003, character #170): (0) approximately as high as postacetabular part (excluding the ventral expansion): (1) significantly higher than postacetabular part
290. **(ordered) Cuppedicus fossa** (Kirkland et al, character #164): (0) deep, ventrally concave; (1) fossa shallow or flat, with no lateral overhang; (2) absent
291. **Cuppedicus fossa position** (Kirkland et al, character #163; certain taxa scored from character 264 of Smith et al 2007 supplementary info, with state (0) coded as (0) for character 306, states (1) and (2) coded as for 306 and state (1) coded as state (1) and state (2) coded as state (0)): (0) ridge bounding fossa 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
292. **Preacetabular portion of ilium** (Kirkland et al, character #229): (0) parasagittal; (1) moderately laterally flaring
293. **Brevis fossa shape** (Rauhut 2003, character #176. Kirkland et at, character #161): (0) shelf-like, narrow with subparallel margins; (1) deeply concave, expanded posteriorly with lateral overhang
294. **Brevis fossa lateral view** (Turner et al, 2007 #217): (0) Poorly developed adjacent to ischial peduncle, without lateral overhang and medial edge of the brevis fossa is visible; (1) well developed fossa along full length of postacetabular blade, lateral overhang extends along full length of fossa, medial edge of brevis fossa covered in lateral view
295. **Medial brevis shelf** (Longrich and Currie, 2008 #53): (0) strongly developed, projects medially; (1) low ridge on medial surface of postacetabular ala
296. **Postacetabular ala of ilium in lateral view** (Kirkland et al, character #158; also Rauhut, 2003, character #174; certain taxa scored from character 260 of Smith et al 2007 supplementary info): (0) squared; (1) acuminate
297. **Articulation of iliac blades with sacrum** (Rauhut, 2003, character #171): (0) vertical, well-separated above sacrum; (1) strongly inclined mediodorsally, almost contacting each other or sacral neural spines at midline
298. **Vertical ridge on iliac blade above acetabulum** (Rauhut, 2003, character #172): (0) absent or poorly developed; (1) well-developed
299. **Pubic peduncle of ilium** (Rauhut, 2003, character #175; certain taxa scored from character #265 of Smith et al 2007 supplementary info): (0) transversely broad and roughly triangular in outline; (1) anteroposteriorly elongated and narrow
300. **Pubic peduncle** (Rauhut, 2003, character #177; certain taxa scored from character #266 of Smith et al 2007 supplementary info; Character state (2) added by JNC and first mentioned in Martinelli and Vera 2007, page 7): (0) subequal in length to ischial peduncle; (1) significantly longer than ischial peduncle, ischial peduncle tapering ventrally and without clearly defined articular facet; (2) craniocaudally shorter than the ischial peduncle
301. **Articulation facet of pubic peduncle of ilium** (Rauhut, 2003, character #178): (0) facing more ventrally than anteriorly, and without a pronounced kink; (1) with pronounced kink and anterior part facing almost entirely anteriorly
302. **Anterior margin of pubic peduncle** (Rauhut, 2003, character #179): (0) straight or convex; (1) concave
303. **Supraacetabular crest:** (0) absent; (1) present
304. **Supraacetabular crest on ilium** (Kirkland et al, character #157): (0) separate process from antitrochanter, forms hood over femoral head; (1) reduced, not forming hood
305. **Antitrochanter posterior to acetabulum** (Kirkland et al, character #162; certain taxa scored from character 269 of Smith et al 2007 supplementary info with states reversed): (0) absent or poorly developed; (1) prominent

306. **Postacetabular blades of ilia in dorsal view** (Kirkland et al, character #159): (0) parallel; (1) diverge posteriorly
307. **Tuber along dorsal edge of ilium, dorsal or slightly posterior to acetabulum** (Kirkland et al, character #160; certain taxa scored from character 259 of Smith et al 2007 supplementary info): (0) absent; (1) present
308. **Dorsal margin of postacetabular ala in lateral view** (Turner et al 2007 #226; Originally in Novas, 2004): (0) convex or straight; (1) concave, brevis shelf extends caudal to lateral ilium making it appear concave in lateral view
309. **Caudal end of postacetabular ala in dorsal view** (Turner et al 2007 #227; Originally in Makovicky et al 2003): (0) rounded or squared in dorsal view; (1) lobate, with brevis shelf extending caudally beyond caudal terminus of the postacetabular ala
310. **Ilium and ischium articulation** (Kirkland et al, character #227; certain taxa scored from character 274 of Smith et al 2007 supplementary info): (0) flat or slightly concavo-convex; (1) with process projecting into socket in ischium
311. **(ordered) Pubic orientation** (Kirkland et al, 2005 #175; certain taxa scored from character 252 of Smith et al 2007 supplementary info): (0) propubic; (1) vertical (Acc. to Kirkland et al, 2005 #175): (2) moderately posteriorly oriented; (3) opisthopubic
312. **Strongly expanded pubic boot** (Rauhut, 2003 #184; also coded with respect to Kirkland et al, 2005 #176, state (2) (no anterior or posterior projections): originally in Gauthier 1986; certain taxa scored from character 280 of Smith et al 2007 supplementary info): (0) absent; (1) present
313. **Pubic boot projects** (Kirkland et al, 2005 #176; see also Rauhut, 2003 #s 184-187.): (0) anteriorly and posteriorly; (1) with little or no anterior process; (2) only expanded anteriorly (Need to do research to code this state)
314. **(ordered) Pubic apron** (Kirkland et al, character #177; also see Rauhut, 2003 #167 (need to do further research to recode)): (0) extends medially from middle of cylindrical pubic shaft; (1) shelf extends medially from anterior edge of anteroposterioly flattened shaft; (2) absent
315. **Pubic apron** (Kirkland et al, character #179; certain taxa scored from character 278 of Smith et al 2007 supplementary info): (0) about half of pubic shaft length; (1) less than 1/3 of shaft length
316. **Pubic apron** (Rauhut, 2003, character #182; certain taxa scored from character 279 of Smith et al 2007 supplementary info): (0) completely closed; (1) with medial opening distally above the pubic boot
317. **(ordered) Obturator foramen in pubis** (Rauhut, 2003, character #180; originally in Holtz 1994; certain taxa scored from character #276 of Smith et al 2007 supplementary info): (0) completely enclosed; (1) open ventrally (obturator notch): (2) absent
318. **Pubic fenestra below obturator foramen** (Rauhut, 2003, character #181; certain taxa scored from character #277 of Smith et al 2007 supplementary info): (0) absent; (1) present
319. **Pubic shafts in lateral view** (Rauhut, 2003, character #183; also Kirkland et al, character #178 (where state (1) is recoded as state (2))): (0) straight; (1) anteriorly convex; (2) anteriorly concave
320. **Lateral face of pubic shafts** (Turner et al 2007 #231; originally in Senter 2004): (0) smooth; (1) with prominent lateral tubercle about halfway down the shaft
321. **Length of Ischium** (Kirkland et al, character #171; also Rauhut, 2003, character #191; originally from Gauthier 1986; certain taxa scored from character 284 of Smith et al 2007 supplementary info): (0) more than two-thirds pubis length; (1) two thirds or less of pubic length
322. **Obturator process of ischium** (Kirkland et al, character #167; also Rauhut, 2003, character #189 (with state (0) recoded as (1) and state (1) recoded as (3)): (0) absent; (1) proximal in position; (2) located near middle of ischiadic shaft; (3) located at distal end of ischium
323. **Ischiac shaft** (Turner et al 2007 #166; originally in Makovicky et al 2005): (0) Rodlike; (1) anteroposteriorly wide and plate-like

324. **Lateral blade of ischium** (Turner 2007 #168): (0) flat; (1) laterally concave; (2) with longitudinal ridge subdividing lateral surface into anterior (including obturator process) and posterior parts
325. **Ischium** (Kirkland et al, character #166): (0) straight; (1) ventrodistally curved anteriorly; (2) twisted at midshaft and with flexure of obturator process toward midline so that distal end is horizontal; (3) with laterally concave curvature in anterior view; (4) distal portion curved posteriorly
326. **Contact of obturator process of ischium** (Kirkland et al, character #168): (0) does not contact pubis; (1) contacts pubis
327. **Ventral notch at distal edge of ischial obturator process** (Rauhut 2003, character #190; originally in Sereno et al 1996; certain taxa scored from character 289 of Smith et al 2007 supplementary info): (0) absent, grades smoothly into ischial shafts; (1) present, makes obturator process triangular in lateral view
328. **Obturator process on ischium** (Rauhut 2003, character #188. Also Kirkland et al, character #169 (with states reversed); certain taxa scored from character #287 of Smith et al 2007 supplementary info): (0) confluent with pubic peduncle; (1) offset from pubic peduncle by a distinct notch
329. **Morphology of offset triangular obturator process of ischium** (Turner et al 2007 #234): (0) wide base along ischiac shaft, rostral process short; (1) narrow base, rostral process elongate
330. **Distal end of ischium** (Rauhut 2003, character #193. Also Kirkland et al, character #173; certain taxa scored from character #290 of Smith et al 2007 supplementary info): (0) slightly expanded; (1) strongly expanded, forming ischial "boot"; (2) tapering
331. **(ordered) Distal ends of ischia** (Kirkland et al, character #172; certain taxa scored from character #291 of Smith et al 2007 supplementary info): (0) form symphysis; (1) approach one another but do not form symphysis; (2) widely separated
332. **Distally placed process on caudal margin of ischium** (Turner et al 2007 #232; originally Forster et al 1998): (0) absent; (1) present
333. **Tubercle on anterior edge of ischium** (Kirkland et al, character #174; certain taxa scored from character 285 of Smith et al 2007 supplementary info): (0) absent; (1) present
334. **Posterior process (ischial tuberosity) on posteroproximal part of ischium** (Rauhut, 2003, character #192; Kirkland et al, character #165; certain taxa scored from character #286 of Smith et al 2007 supplementary info): (0) absent; (1) well-developed
335. **Form of posteroproximal ischial process (ischial tuberosity)** (Turner et al, 2007 #230): (0) small, tablike; (1) large, proximodorsally hooked and separated from the iliac peduncle by a notch
336. **Semicircular scar on posterior part of the proximal end of the ischium** (Kirkland et al, character #170): (0) absent; (1) present
337. **Femoral length** (Zhang et al 2008 #309): (0) longer than tibia; (1) shorter than tibia
338. **Femoral head** (Kirkland et al, character #180; also Rauhut, 2003, character #197; fovea ligamentum capitis of Baumel and Witmer 1993:64): certain taxa scored from character 295 of Smith et al 2007 supplementary info): (0) without fovea capitalis; (1) circular fovea present in center of medial surface of head
339. **Oblique ligament groove on the posterior surface of femoral head** (Originally in Rauhut 2003, all scorings taken from Smith et al 2007 #296): (0) absent or very shallow; (1) deep, bound medially by a well-developed posterior lip
340. **Femoral head** (Rauhut, 2003, character #194; Originally in Holtz 1994; certain taxa scored from character 292 of Smith et al 2007 supplementary info): (0) confluent with greater trochanter; (1) separated from greater trochanter by a distinct cleft
341. **Femoral head (2)** (Rauhut, 2003, character #195; certain taxa scored from character 293 of Smith et al 2007 supplementary info): (0) directed anteromedially; (1) directed strictly medially

342. **Greater trochanter** (Rauhut, 2003, character #196): (0) anteroposteriorly narrow and narrowing from medial to lateral; (1) anteroposteriorly expanded, forming a trochanteric crest
343. **(ordered) Lesser trochanter** (Kirkland et al, 2005 #181): (0) separated from greater trochanter by a deep cleft; (1) trochanters separated by small groove; (2) completely fused (or absent) to form crista trochanteris (Additional taxa coded using state (3) of Rauhut, 2003 #198 "fused with greater trochanter")
344. **Lesser trochanter shape** (Kirkland et al, 2005 #181): (0) alariform; (1) cylindrical in cross section
345. **Placement of lesser trochanter** (Rauhut, 2003 #199; certain taxa scored from character 298 of Smith et al 2007 supplementary info): (0) at distal end of femoral head; (1) more proximally placed, but distal to greater trochanter; (2) as proximal or more proximal than greater trochanter
346. **Vertical ridge on lesser trochanter** (Kirkland et al, character #215): (0) present; (1) absent
347. **Posterolateral trochanter** (Kirkland et al, character #183; also Rauhut, 2003, character #200; Turner et al 2007 call this the "lateral ridge"): (0) absent or represented only by rugose area; (1) posterior trochanter distinctly raised from shaft, mound-like
348. **Fourth trochanter on femur** (Kirkland et al, character #184; also Rauhut, 2003, character #201; originally Gauthier 1986; certain taxa scored from character 301 of Smith et al 2007 supplementary info): (0) present; (1) absent
349. **Accessory trochanteric crest distal to lesser trochanter** (Kirkland et al, character #185): (0) absent; (1) present
350. **Broad groove on cranial surface of distal femur** (Rauhut, 2003, character #202; also Kirkland et al, character #186; Originally in Forster 1999; certain taxa scored from character 302 of Smith et al 2007 supplementary info): (0) absent or poorly developed; (1) well developed and bounded medially by an expanded medial lamella
351. **Popliteal fossa on distal end of femur** (Kirkland et al, character #187): (0) open distally; (1) closed off distally by contact between distal condyles
352. **Distal end of femur** (Rauhut, 2003, character #203): (0) anteroposteriorly broad and distally flattened; (1) less broad and well rounded
353. **Lateral femoral distal condyle;** (0) distally rounded, projects only slightly more distally than medial condyle; (1) distally conical, projects considerably further distally than medial condyle
354. **Lateral accessory cnemial crest** (Added by JNC): (0) absent; (1) present
355. **Medial cnemial crest** (Kirkland et al, character #192: this crest is a medial projection off of a greatly enlarged cnemial crest, homologous (perhaps) to the condition found in birds.): (0) absent; (1) present on proximal end of tibia
356. **Fibular condyle on proximal end of tibia** (Rauhut, 2003, character #204; certain taxa scored from character 305 of Smith et al 2007 supplementary info): (0) confluent with cnemial crest anteriorly in proximal view; (1) strongly offset from cnemial crest
357. **Medial proximal condyle on tibia;** (0) round in proximal view; (1) arcuate and posteriorly angular in proximal view
358. **Posterior cleft between medial part of the proximal end of the tibia and fibular condyle** (Rauhut, 2003, character #205; certain taxa scored from character 307 of Smith et al 2007 supplementary info): (0) absent; (1) present
359. **(ordered) Fibular crest (ridge on lateral side of tibia for connection with fibula)** (Rauhut, 2003, character #206; originally in Gauthier 1986; certain taxa scored from character #308 of Smith et al 2007 supplementary info): (0) absent; (1) present, extending from proximal articular surface distally; (2) present, clearly separated from proximal articular surface
360. **Shape of fibular crest** (Longrich and Currie 2008 #64): (0) quadrangular; (1) low and rounded

361. **Bracing for ascending process of astragalus on anterior side of distal tibia** (Rauhut, 2003, character #207): (0) distinct 'step' running obliquely from mediodistal to lateroproximal; (1) bluntly rounded vertical ridge on medial side; (2) anterior side of tibia flat
362. **Fibula** (Kirkland et al, 2005 #188): (0) reaches proximal tarsals; (1) short, tapering distally, and not in contact with proximal tarsals
363. **Insertion of *m. iliofibularis* on fibular shaft** (Rauhut, 2003, character #211; certain taxa scored from character #316 of Smith et al 2007 supplementary info; originally in Mader and Bradley 1989, also Holtz 1994): (0) not especially marked; (1) present as a well-developed anterolateral tubercle
364. **Ridge on medial side of proximal end of fibula, that runs anterodistally from the posterproximal end** (Rauhut, 2003, character #209; Originally in Rowe and Gauthier, 1990; certain taxa scored from character #314 of Smith et al 2007 supplementary info): (0) absent; (1) present
365. **Medial surface of proximal end of fibula** (Kirkland et al, character #189. Also see Rauhut 2003, character #210; Originally from Sereno et al 1996; certain taxa scored from character #315 of Smith et al 2007 supplementary info with states reversed): (0) concave along long axis; (1) flat
366. **Deep oval fossa on medial surface of fibula near proximal end** (Kirkland et al, character #190. Also see Rauhut 2003, character #210): (0) absent; (1) present
367. **Astragalus and calcaneum** (Kirkland et al, character #191): (0) condyles indistinct or poorly separated; (1) distinct condyles separated by prominent vertical tendinal groove on anterior surface
368. **Astragalus and calcaneum*2** (Kirkland et al, character #195; Sereno et al 1996; certain taxa scored from character 327 of Smith et al 2007 supplementary info): (0) separate from tibia; (1) fused to each other and to the tibia in late ontogeny
369. **Fibular facet on astragalus** (Rauhut 2003, character #213): (0) large and facing partially proximally; (1) reduced and facing laterally or absent
370. **(ordered) Height of ascending process of the astragalus** (Rauhut, 2003 #215; certain taxa scored from character321 of Smith et al 2007 supplementary info): (0) lower than astragalar body; (1) higher than astragalar body; (2) more than twice the height of astragalar body
371. **Shape of ascending process of the astragalus** (Kirkland et al, 2005 #193): (0) tall and broad, covering most of anterior surface of distal end of tibia; (1) short and slender, covering only lateral half of anterior surface of tibia; (2) tall with a medial notch that restricts it to lateral side of anterior face of distal tibia
372. **Ascending process of astragalus** (Rauhut, 2003, character #216; also Kirkland et al, character #194; certain taxa scored from character 322 of Smith et al 2007 supplementary info; Originally from Welles and Long 1974): (0) confluent or only slightly offset from astragalar body; (1) offset from astragalar body by a pronounced groove
373. **Astragalar condyles** (Rauhut, 2003, character #217; Originally in Sereno et al 1996; certain taxa scored from character 324 of Smith et al 2007 supplementary info): (0) almost entirely below tibia and face distally; (1) significantly expanded proximally on anterior side of tibia and face anterodistally
374. **Horizontal groove across astragalar condyles anteriorly** (Rauhut, 2003, character #218; Originally in Welles and Long, 1974; certain taxa scored from character 325 of Smith et al 2007 supplementary info): (0) absent; (1) present
375. **Calcaneum** (Rauhut 2003, character #219): (0) without facet for tibia; (1) well-developed facet for tibia present
376. **Distal tarsals** (Kirkland et al, character #196; certain taxa scored from character 329 of Smith et al 2007 supplementary info): (0) separate, not fused to metatarsals; (1) form metatarsal cap with intercondylar prominence that fuses to metatarsal early in postnatal ontogeny

377. **Metatarsals** (Kirkland et al, character #197): (0) not co-ossified; (1) co-ossification of metatarsals begins proximally; (2) begins distally
378. **Metatarsal I;** (0) present; (1) absent
379. **Metatarsal I** (Kirkland et al, character #203): (0) attenuates proximally ,without proximal articulating surface; (1) proximal end of Mt I similar to that of Mt II-IV
380. **(ordered) Metatarsal I** (Rauhut 2003, character #222 and Kirkland et al, character #202, with state (3) added): (0) contacts the ankle joint (Rauhut 2003, character 222: state (0): Possibly Kirkland et al, state (2)): (1) reduced, elongated and splint-like, articulates in the middle of the medial surface of Mt II (Rauhut #222, state (1). Also Kirkland et al #202: state (0)): (2) broadly triangular and attached to the distal quarter of Mt II (Rauhut #222 state (2), Kirkland et al #202 state (1))
381. **Distal end of metatarsal II** (Kirkland et al, character #198): (0) smooth, not ginglymoid; (1) with developed ginglymus
382. **Tuber along extensor surface of MtII** (Turner et al 2007; from Chiappe 2002): (0) Absent; (1) Present (Turner et al 2004 #235, originally Chiappe 2002)
383. **Posteromedial margin MtII diaphysis** (Though not included in Turner's dataset, this seems to be developed independently of MtIV's ridge): (0) well-developed flange absent or area rugose; (1) with flange projecting caudally or medially
384. **Distal end of metatarsal III** (Kirkland et al, character #199): (0) smooth, not ginglymoid; (1) with developed ginglymus
385. **(ordered) Metatarsal III** (Rauhut 2003, character #220, with state (2) added from Kirland et al, character #200.): (0) subequal in width to Mt II and IV proximally (see Kirkland et al, character #200 state (0)): (1) pinched between II and IV and not visible in anterior view proximally; (2) does not reach the proximal end of the metatarsus
386. **Shaft of MT IV** (Kirkland et al, character #204): (0) round or thicker dorsoventrally than wide in cross section; (1) shaft of Mt IV mediolaterally widened and flat in cross section
387. **Length of MtIV** (Taken from Longrich and Currie, 2008; originally in somebody else, but can't remember who): (0) subequal to Mt II; (1) markedly longer than Mt II
388. **Posterolateral margin oF MtIV diaphysis** (Turner et al 2007 #229; originally in Novas and Pol 2005): (0) well-developed flange absent or area rugose (In *Allosaurus*, Tyrannosaurids, a flattened, ridge-like and long rugosity is present in this area): (1) with flange projecting caudally or laterally
389. **Metatarsal V** (Rauhut, 2003, character #223): (0) with rounded distal articular facet; (1) strongly reduced and lacking distal articular facet; (2) short, without articular surface, transversely flattened and bowed anteriorly distally
390. **Pedal digit IV** (Rauhut 2003, character #221; see also Kirkland et al, character #205): (0) significantly shorter than III and subequal in length to II, foot is symmetrical; (1) significantly longer than II and only slightly shorter than III, foot is asymmetrical
391. **Ungual and penultimate phalanx of pedal digit II** (Kirkland et al, character #201; also Rauhut, 2003, character #224): (0) similar to those of III; (1) highly modified for extreme hyper-tension, ugual more strongly curved and about 50% larger than that of III
392. **Pedal phalanges of digit IV;** (0) anteroposteriorly short, with proximal and distal articular surfaces very close together, particularly in distal elements; (1) anteroposteriorly long, proximal and distal articular surfaces well-separated
393. **Extensor ligament pits on dorsal surface of pedal phalanges** (Turner, personal communication): (0) shallow, extensor ridges not sharp; (1) deep and extensive proximally, corresponding extensor ridges sharply defined in dorsal view
394. **Proximodorsal ‘lip’ on some manual unguals - a transverse ridge immediately dorsal to the articulating surface** (Kirkland et al, character #153; also Rauhut, 2003, character #162; Originally from Currie and Russell 1988; certain taxa scored from character #250 of Smith et al 2007 supplementary info): (0) absent; (1) present

395. **(ordered) Flexor tubercle placement** (Zhang et al 2008 #151): (0) proximal; (1) distal; (2) absent; (3) reduced to pyramidal nubbins, as in Limusaurus
396. **Flexor tubercle size** (Zhang et al 2008 #348): (0) large (> 1/3 articular facet height): (1) small (< 1/3 articular facet height)
397. **Lateral grooves of manual ungual I-2 in ventral view** (Longrich and Currie, 2008 #45): (0) unenclosed; (1) proximal end of grooves partially enclosed by lateral notches; (2) proximal end of grooves passes through foramena on ventral surface of ungual

"Dynamic" characters

398. **Digit I:** (0) absent; (1) present
399. **Metacarpal of digit I:** (0) shorter than longest metacarpal of manus; (1) longest metacarpal of manus
400. **(ordered) Number of phalanges, digit I:** (0) zero; (1) one; (2) two; (3) three; (4) four
401. **Tab on dorsomedial aspect of metacarpal I, overlapping adjacent metacarpal:** (0) absent; (1) present
402. **Ventrolateral tab on the proximolateral surface of metacarpal I:** (0) absent; (1) present
403. **(ordered) Metacarpal shape, digit I:** (0) twice as long as broad or longer; (1) longer than broad; (2) broader than long
404. **(ordered) Metacarpal position, digit I:** (0) only contacts medial neighbor at base; (1) contacts medial neighbor for 50% shaft length; (2) almost or completely appressed to neighbor
405. **Metacarpal proximodistal lenth, digit I:** (0) approximately equal to other metacarpals; (1) 50% or less of longer metacarpals
406. **Metacarpal shaft, digit I:** (0) straight; (1) bowed
407. **Metacarpal I shaft diameter** (Rauhut, 2003, character #151; certain taxa scored from character 239 of Smith et al 2007 supplementary info): (0) about the same as other metacarpals; (1) extremely thin, 70% or less the diameter of other metacarpals
408. **Medial metacarpal surface, digit I;** (0) unexpanded; (1) expanded proximally
409. **Proximal articular metacarpal surface, digit I:** (0) mediolaterally as broad as dorsoventrally tall; (1) mediolaterally narrow, dorsoventrally tall
410. **Rectangular buttress, metacarpal I:** (0) absent; (1) present
411. **Shape of proximal metacarpal articulation, digit I:** (0) subrectangular; (1) triangular, apex dorsal
412. **Distal metacarpal articulation, digit I:** (0) smooth, rounded; (1) ginglymoid
413. **(ordered) Distal metacarpal condyles, digit I:** (0) symmetrical; (1) asymmetrical; (2) absent
414. **Distal dorsal metacarpal surface, digit I:** (0) smooth or with very shallow extensor pit; (1) extensor pits deep and well-developed
415. **(ordered) Length ratio phalanx I-1 to metacarpal I:** (0) less than or equal to (1): (1) between 1 and 1.5; (2) greater than or equal to 1.5
416. **Flexor surface, phalanx I-1** (Added by JNC 2008-07-28 with reference to Chiappe et al 2003): (0) convex or flat; (1) with concave axial furrow
417. **Ratio shaft diameter of manual phalanx I-1 to radius** (Kirkland et al, character #207; certain taxa scored from character 246 of Smith et al 2007 supplementary): (0) less than; (1) greater than
418. **Penultimate phalanx length, digit I:** (0) longer than each of the other phalanges; (1) longer than all other phalanges combined; (2) about the same as other phalanges; (3) shorter than each of the other phalanges
419. **(ordered) Manual ungual size, digit I:** (0) about the same as other unguals; (1) larger than other unguals; (2) smaller than other unguals; (3) absent
420. **(ordered) Curvature of manual ungual, digit I** (Zhang et al 2008 #299): (0) strongly curved; (1) weakly curved; (2) straight

421. **Proximal articular surface of manual ungual, digit I:** (0) dorsoventrally taller than mediolaterally wide; (1) as wide as tall
422. **Digit II:** (0) absent; (1) present
423. **Metacarpal of digit II:** (0) shorter than longest metacarpal of manus; (1) longest metacarpal of manus
424. **(ordered) Number of phalanges, digit II:** (0) zero; (1) one; (2) two; (3) three; (4) four
425. **Tab on dorsomedial aspect of metacarpal II, overlapping adjacent metacarpal:** (0) absent; (1) present
426. **Ventrolateral tab on the proximolateral surface of metacarpal II:** (0) absent; (1) present
427. **(ordered) Metacarpal shape, digit II:** (0) twice as long as broad or longer; (1) longer than broad; (2) broader than long
428. **(ordered) Metacarpal position, digit II:** (0) only contacts medial neighbor at base; (1) contacts medial neighbor for 50% shaft length; (2) almost or completely appressed to neighbor
429. **Metacarpal proximodistal lenth, digit II:** (0) approximately equal to other metacarpals; (1) 50% or less of longer metacarpals
430. **Metacarpal shaft, digit II:** (0) straight; (1) bowed
431. **Metacarpal II shaft diameter:** (0) about the same as other metacarpals; (1) extremely thin, 70% or less the diameter of other metacarpals
432. **Medial metacarpal surface, digit II:** (0) unexpanded; (1) expanded proximally
433. **Proximal articular metacarpal surface, digit II:** (0) mediolaterally as broad as dorsoventrally tall; (1) mediolaterally narrow, dorsoventrally tall
434. **Rectangular buttress, metacarpal II:** (0) absent; (1) present
435. **Shape of proximal metacarpal articulation, digit II:** (0) subrectangular; (1) triangular, apex dorsal
436. **Distal metacarpal articulation, digit II:** (0) smooth, rounded; (1) ginglymoid
437. **(ordered) Distal metacarpal condyles, digit II:** (0) symmetrical; (1) asymmetrical; (2) absent
438. **Distal dorsal metacarpal surface, digit II:** (0) smooth or with very shallow extensor pit; (1) extensor pits deep and well-developed
439. **(ordered) Length ratio phalanx II-1 to metacarpal II:** (0) less than or equal to (1): (1) between 1 and 1.5; (2) greater than or equal to 1.5
440. **Flexor surface, phalanx II-1:** (0) convex or flat; (1) with concave axial furrow
441. **Ratio shaft diameter of manual phalanx II-1 to radius;** (0) less than; (1) greater than
442. **Penultimate phalanx length, digit II:** (0) longer than each of the other phalanges; (1) longer than all other phalanges combined; (2) about the same as other phalanges; (3) shorter than each of the other phalanges
443. **(ordered) Manual ungual size, digit II:** (0) about the same as other unguals; (1) larger than other unguals; (2) smaller than other unguals; (3) absent
444. **(ordered) Curvature of manual ungual, digit II:** (0) strongly curved; (1) weakly curved; (2) straight
445. **Proximal articular surface of manual ungual, digit II:** (0) dorsoventrally taller than mediolaterally wide; (1) as wide as tall
446. **Digit III:** (0) absent; (1) present
447. **Metacarpal of digit III:** (0) shorter than longest metacarpal of manus; (1) longest metacarpal of manus
448. **(ordered) Number of phalanges, digit III:** (0) zero; (1) one; (2) two; (3) three
    a. 4 four
449. **Tab on dorsomedial aspect of metacarpal III, overlapping adjacent metacarpal;** (0) absent; (1) present
450. **Ventrolateral tab on the proximolateral surface of metacarpal III:** (0) absent; (1) present

451. **(ordered) Metacarpal shape, digit III:** (0) twice as long as broad or longer; (1) longer than broad; (2) broader than long
452. **(ordered) Metacarpal position, digit III:** (0) only contacts medial neighbor at base; (1) contacts medial neighbor for 50% shaft length; (2) almost or completely appressed to neighbor
453. **Metacarpal proximodistal lenth, digit III:** (0) approximately equal to other metacarpals; (1) 50% or less of longer metacarpals
454. **Metacarpal shaft, digit III:** (0) straight; (1) bowed
455. **Metacarpal X shaft diameter;** (0) about the same as other metacarpals; (1) extremely thin, 70% or less the diameter of other metacarpals
456. **Medial metacarpal surface, digit III:** (0) unexpanded; (1) expanded proximally
457. **Proximal articular metacarpal surface, digit III:** (0) mediolaterally as broad as dorsoventrally tall; (1) mediolaterally narrow, dorsoventrally tall
458. **Rectangular buttress, metacarpal III:** (0) absent; (1) present
459. **Shape of proximal metacarpal articulation, digit III:** (0) subrectangular; (1) triangular, apex dorsal
460. **Distal metacarpal articulation, digit III:** (0) smooth, rounded; (1) ginglymoid
461. **(ordered) Distal metacarpal condyles, digit III:** (0) symmetrical; (1) asymmetrical; (2) absent
462. **Distal dorsal metacarpal surface, digit III:** (0) smooth or with very shallow extensor pit; (1) extensor pits deep and well-developed
463. **(ordered) Length ratio phalanx III-1 to metacarpal III:** (0) less than or equal to (1): (1) between 1 and 1.5; (2) greater than or equal to 1.5
464. **Flexor surface, phalanx III-1:** (0) convex or flat; (1) with concave axial furrow
465. **Ratio shaft diameter of manual phalanx III-1 to radius:** (0) less than; (1) greater than
466. **Penultimate phalanx length, digit III:** (0) longer than each of the other phalanges; (1) longer than all other phalanges combined; (2) about the same as other phalanges; (3) shorter than each of the other phalanges
467. **(ordered) Manual ungual size, digit III:** (0) about the same as other unguals; (1) larger than other unguals; (2) smaller than other unguals; (3) absent
468. **(ordered) Curvature of manual ungual, digit III:** (0) strongly curved; (1) weakly curved; (2) straight
469. **Proximal articular surface of manual ungual, digit III:** (0) dorsoventrally taller than mediolaterally wide; (1) as wide as tall
470. **Digit IV:** (0) absent; (1) present
471. **Metacarpal of digit IV:** (0) shorter than longest metacarpal of manus; (1) longest metacarpal of manus
472. **(ordered) Number of phalanges, digit IV:** (0) zero; (1) one; (2) two; (3) three; (4) four
473. **Tab on dorsomedial aspect of metacarpal IV, overlapping adjacent metacarpal:** (0) absent; (1) present
474. **Ventrolateral tab on the proximolateral surface of metacarpal IV:** (0) absent; (1) present
475. **(ordered) Metacarpal shape, digit IV:** (0) twice as long as broad or longer; (1) longer than broad; (2) broader than long
476. **(ordered) Metacarpal position, digit IV:** (0) only contacts medial neighbor at base; (1) contacts medial neighbor for 50% shaft length; (2) almost or completely appressed to neighbor
477. **Metacarpal proximodistal lenth, digit IV:** (0) approximately equal to other metacarpals; (1) 50% or less of longer metacarpals
478. **Metacarpal shaft, digit IV:** (0) straight; (1) bowed
479. **Metacarpal IV shaft diameter:** (0) about the same as other metacarpals; (1) extremely thin, 70% or less the diameter of other metacarpals
480. **Medial metacarpal surface, digit IV:** (0) unexpanded; (1) expanded proximally

481. **Proximal articular metacarpal surface, digit IV:** (0) mediolaterally as broad as dorsoventrally tall; (1) mediolaterally narrow, dorsoventrally tall
482. **Rectangular buttress, metacarpal IV:** (0) absent; (1) present
483. **Shape of proximal metacarpal articulation, digit IV:** (0) subrectangular; (1) triangular, apex dorsal
484. **Distal metacarpal articulation, digit IV:** (0) smooth, rounded; (1) ginglymoid
485. **(ordered) Distal metacarpal condyles, digit IV:** (0) symmetrical; (1) asymmetrical; (2) absent
486. **Distal dorsal metacarpal surface, digit IV:** (0) smooth or with very shallow extensor pit; (1) extensor pits deep and well-developed
487. **(ordered) Length ratio phalanx IV-1 to metacarpal IV:** (0) less than or equal to (1): (1) between 1 and 1.5; (2) greater than or equal to 1.5
488. **Flexor surface, phalanx IV-1:** (0) convex or flat; (1) with concave axial furrow
489. **Ratio shaft diameter of manual phalanx IV-1 to radius:** (0) less than; (1) greater than
490. **Penultimate phalanx length, digit IV:** (0) longer than each of the other phalanges; (1) longer than all other phalanges combined; (2) about the same as other phalanges; (3) shorter than each of the other phalanges
491. **(ordered) Manual ungual size, digit IV:** (0) about the same as other unguals; (1) larger than other unguals; (2) smaller than other unguals; (3) absent
492. **(ordered) Curvature of manual ungual, digit IV:** (0) strongly curved; (1) weakly curved; (2) straight
493. **Proximal articular surface of manual ungual, digit IV:** (0) dorsoventrally taller than mediolaterally wide; (1) as wide as tall
494. **Digit V:** (0) absent; (1) present
495. **Metacarpal of digit V:** (0) shorter than longest metacarpal of manus; (1) longest metacarpal of manus
496. **(ordered) Number of phalanges, digit V:** (0) zero; (1) one; (2) two; (3) three
    a. 4 four
497. **Tab on dorsomedial aspect of metacarpal V, overlapping adjacent metacarpal:** (0) absent; (1) present
498. **Ventrolateral tab on the proximolateral surface of metacarpal V:** (0) absent; (1) present
499. **(ordered) Metacarpal shape, digit V:** (0) twice as long as broad or longer; (1) longer than broad; (2) broader than long
500. **(ordered) Metacarpal position, digit V:** (0) only contacts medial neighbor at base; (1) contacts medial neighbor for 50% shaft length; (2) almost or completely appressed to neighbor
501. **Metacarpal proximodistal lenth, digit V:** (0) approximately equal to other metacarpals; (1) 50% or less of longer metacarpals
502. **Metacarpal shaft, digit V:** (0) straight; (1) bowed
503. **Metacarpal V shaft diameter:** (0) about the same as other metacarpals; (1) extremely thin, 70% or less the diameter of other metacarpals
504. **Medial metacarpal surface, digit V:** (0) unexpanded; (1) expanded proximally
505. **Proximal articular metacarpal surface, digit V:** (0) mediolaterally as broad as dorsoventrally tall; (1) mediolaterally narrow, dorsoventrally tall
506. **Rectangular buttress, metacarpal V:** (0) absent; (1) present
507. **Shape of proximal metacarpal articulation, digit V:** (0) subrectangular; (1) triangular, apex dorsal
508. **Distal metacarpal articulation, digit V:** (0) smooth, rounded; (1) ginglymoid
509. **(ordered) Distal metacarpal condyles, digit V:** (0) symmetrical; (1) asymmetrical; (2) absent
510. **Distal dorsal metacarpal surface, digit V:** (0) smooth or with very shallow extensor pit; (1) extensor pits deep and well-developed

511. **(ordered) Length ratio phalanx V-1 to metacarpal V:** (0) less than or equal to (1): (1) between 1 and 1.5; (2) greater than or equal to 1.5
512. **Flexor surface, phalanx V-1:** (0) convex or flat; (1) with concave axial furrow
513. **Ratio shaft diameter of manual phalanx V-1 to radius:** (0) less than; (1) greater than
514. **Penultimate phalanx length, digit V:** (0) longer than each of the other phalanges; (1) longer than all other phalanges combined; (2) about the same as other phalanges; (3) shorter than each of the other phalanges
515. **(ordered) Manual ungual size, digit V:** (0) about the same as other unguals; (1) larger than other unguals; (2) smaller than other unguals; (3) absent
516. **(ordered) Curvature of manual ungual, digit V:** (0) strongly curved; (1) weakly curved; (2) straight
517. **Proximal articular surface of manual ungual, digit V:** (0) dorsoventrally taller than mediolaterally wide; (1) as wide as tall

Matrix

Tetanura II-III-IV Matrix

Taxon groups used to construct correspondence matrices are indicated in bold. Some taxon groups are necessarily paraphyletic and thus no formal redefinitions of clades are implied.

Outgroups
Marasuchus
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Herrerasaurus
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1100-000103100000001000011000300011410000000100000100020001011000101010000000 0----
100-01-101010102--------
Zupaysaurus
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Dilophosaurus
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00002-10-000102--------

Coelophysoidea

Coelophysis
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Lophostropheus
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Segisaurus
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Syntarsus
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Ceratosauria

Abelisaurus
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Carnotaurus
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Ceratosaurus
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Majungasaurus
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10100-0000001?100012??1000001???????????????????????????1????????????????????10?????
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Masiakasaurus
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000100000010?01011?10?????1??1111100???00?0?0???
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Noasaurus
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Basal tetanura
Acrocanthosaurus
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Carcharodontosaurus
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Giganotosaurus
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Mapusaurus
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Baryonyx
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Irritator
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Condorraptor
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Cryolophosaurus
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0100?010??0?1??????????0??????0011000??
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Dubreuillosaurus
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????20??????0???????10?0????000?1??00???????0??????0??????????????01?1??????1??00?0??
2????????0????????????111????????????1?0????1?????0????????0???100???0?0???????????[01]
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010??10?????[01]?????????????00?????????????????????????2????0???????????????????????????
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Eustreptospondylus
????1?1?????0?-??10???2?????00????????????????????01?0???1101????0?0101?????10?0?0??1
0????????0???????10?0?????0??1??00???1?????????????????????????0?????????1??00?0??2???
?????0?0?02?11??0?1111??10?110??1?00???0??????????????0???00????????????????????????
?10???00?0??1????????????????????????0??00?010?11?????001????10??0?????0???????????101
?100??0?1?????1?12?0?100???111011?????????????????0???????????????????????????????????
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Afrovenator
????????????101001????20001000?0????????0???10?????11??00??????????0101?????1??????0
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?0?????0202?11????111?0010?10???????[01]???01??????????0?????100?010????????????????
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?010?01?00???10???????0??0????0???111??0?2????0???2????0???0----------------------1020?21

100000011120?-1001131?000001000101????0001????????????????????210???????????????????
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Allosaurus
???0?0100101?0000?000?10?010?0??0??0????11??00000111?0-?11001000-00??010???0?00010
001120?00010??001001100?0011000??011001?10?000000000010010?1?00000101010010200
000010200000000010212001000011100010110000100110010030000?00?0?01101001010100
00?1??10??0001011000000000000000000100000??01001110000000?0000100100000000100?110
0001000011000000-000101000100011010001012?0?10000001101110?002000000?0200000000
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Monolophosaurus
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0001010????????000?????1??00???010?10?010??????????000000100101????000211?10110100
000010200000000011112??10?0?111?101001000?1011100101300??0??????010????????????0??
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Neovenator
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00????????????????1?????????????????2?????????????????0?????0???0???????????????????????
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01??0?1?100?????????????????1???????????00?0?0???000??????????????????????????????????????
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Piatnitzkysaurus
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????1202?10????1110?0100100??1??01??101?0?0?????????0??????????????????????????0????01?0
0?0???10?00???0???0???????1?0?????????000000?????????1????000?01????10-0???0-??11000?
01?00???10??1?12?0??0?????????????????????0???
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Sinraptor
???0000000001000000000100001100000010100000200000011110-?11001100-000?0110000100
00000113000001000000000011000001?000?100100??10?000?000000010010010000?0101000110
1000000100000000000102120010000111010101100001?01000101300?00??0?0?000??????????
?00??1???00?????100100?0????????????????????????11101??000?0?0000010000000011?111000
010000?1000000-00010?000110001010001012?000?0000001001100002000000?0100?000100--
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Torvosaurus
???010??????0-????????200????000????????1?2?100???011??00????????????100??????????0?0?
0???0??????????????????????????00?????0???0???
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000111???????11?10100001000111???????10??01?0011000101?????????????????????????????
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Basal coelurosauria
Coelurus
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0??0110?00?0100??00???1?0????????????????????????????111011010????????????????1010?00
0110001?10?????2?2?100100??1111????????????0?0??????????0----------------------1????????????
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Nqwebasaurus
??????????????????101?2?0??0??????????????????????????110110?1?001??0??01000??????????
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21???????11200?1?0---?0111??????????????0??????????????????????????0?0?????????000111100
00??0?100?0??1????00010??0????????????????????????????1010???00???????????????????????
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0000111101-110113?0000001000101000001010 4-00-001100?10100020100----------------------
Tanycolagreus
???100?00?00????????????????????00??????????????000110-0?????????0??011??????????0001
0??1000???101?????01???10???????
?0??????????????????????????11100?001???001?0????????????00???0???????00????????0001011
0000??0110?01?01000000???110?????????????????????????????111?1???0?????????????????10?0
1000110001010?01?12?20100100?201111000010?0000002001?00000----------------------10201
011000001010200-10011310000000100010?0002000104000-0010100100????000??????????????
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Tugulusaurus
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??0?????????0?????????????????????????????????
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1??01?12?0?????002[01]11101????????????????????0???0----------------------1?20111?0?0000111
21???00??
Ornitholestes
???0000?010?10100?10??1000??11000??00??01?000000010010-?0101?000?10?00001000?0001
00011[23]??????00000??0????0?0??101?1?0?00??11?????00000001000011100010100010 01010
11100102000000000???2?20001?111?1011111001010110?101?0?010?10?0?01110?0?0??1?1?
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?01001?00000-0????????????1?0010???????????0????????????00???0?1000?0?0?1?00000-----------
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Tyrannosauroidea
Albertosaurus
???1?0000011?0????101????????00011?00???002??0000011?????1??0?0??00??111???0?01001
0?10???????0??0??????0???01?000??01?010?10?1?00000000010010?1?01100???010?10??0?10
010?000000000102?20000000????????010000?00??00?0?410?00?10?0?0??0??0?????00000100
?01000010?00?00001001??????1000?0?10000?110?00000?0?10???1000000?010001??0001000
001020000-1???010011000000?0001?12?20100100?20110?00002000010?0?00??00??0-----------
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Daspletosaurus
?????01?0??1?010???0?1000000 1?0011100?????2?000?00111???011??1????????1??????????10
?103?????????0?????????0?????????????10?10?01000?????????1?1???????211????1??0????????
????00000??????????0??1111???????????????1??
?????????01????????????????????????????????????10??010
002????1010?01?12?2????????????????????????????????????00----------------------1?2??1?10?00
?0111???-0??1?3??0200?10?0101???00??1?0??0-1010???020???--??0----------------------

Dilong
10-1000?011?10100110?1000?0001001010000001221000010110-001000100000000012000 1?1
0010011??0?????0000100110000 0???1??1?100??0????????0000001000011111101010 1?1101?
00100102000000000????1?00??0?1?1??0100?????1?????0101????????????0????1?001????000?
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?0??0????11?110001?00??010001?12?201???00020111??0????0?00?0?2?0??000?0----------------
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Guanlong
???1000001111010011 0?10?0???0100101?0000012210100101 1??0?1000100001000010000101
0?100??30??????0000100010000011000110000100101120000000000 10000111??1?0????10?101
0001011020?0000?0?????1?00000011101010010001100100010130001 0?10?0?010??1000?11??
000???????000101?0000??1110000000100000 0?101001111000000?00101011001 0??0110001000
001000001?00000-0?1?0100011000101 0?01?12?2010010001011010000200000000210??0??00-
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Tyrannosaurus
???10000001110101110110000000000 01110010?00221000001110-?111101000001?11122?0101
00100103?00001000001001110?00100001101?01?010?02000000000 1001011?01100101010110
1000100102000000000102120000000 01111?0100100001001100000310?00?10?0?0?0001001111
000001??11??000101000000001001001?00100010?1?0?01111100000?011010110000001010001
100001000001021000-1011010012000110100010 12?20??01000201101000020000100020000000
000----------------------102001110000001 11200-0001131002000100010100000001?0?00-1010?0
?02--------0----------------------
Stokesosaurus_clevelandi
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Stokesosaurus_langhami
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Ornithomimidae
Anserimimus
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Archaeornithomimus
???1???????
???0??1???1?????????????????????????1??-???
?????1?20?1100---?011010000??0?00????311010?10?0?01?00?000???0???????????2011110??0
00?201??01?00100000?????01000000010?0000100100010??01000?2000001010000 10001??10?

010001?01?0010?01?02?????1000??1010?0000?00?110?0?0????11??????????????????????????
?????????????????1?1??10??????????????????????1??????????1????????????1?????????????????
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Gallimimus
???1002100010010??101100?000?000000000000110??000000010-011000000010?0000000?001
11200-???1?010?100?1101000010?0001100001??11?0101000010000011?1?10020???000011-?-
--1-----2---??---10?1?20101011??????010000??0??00???501??0?10?0?0??0??0?????00010??????
?21110?01?010020?0????001000?1??0??01110?00011?0?0????1010000?010100??00010010010
00000-110????00?000110??00?????????0100??01???001?-00?01010?00??01100-------------------
----1020?010000?0?0001?0-01011310010000???0000??0010104-?0-0010?010000??10100--------
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Garudimimus
???1002?00011001?01011000000001000?0100000??010100000010-01100?000-0?0?00?0-001000?
?0?113??1?0100100?11???0001010001100?1?????????0010100000101?10020??????011-?---
1-----2---??--00?10????????????????01?00?0???0?0101401?1???????????0?????????????????????
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?10?010001??011011001?10??00??100?20????0000200?000?02000??????????????????????????
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Harpymimus
??????2?0??????0???0???0?00?????????????????1????????0????????????????0?????????????????
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?0????????????????????????????0????????4??
2??0????001?00?1??0?00111????????0????????????00?????????00??0?1????00????????????????
????????????????????????????001?-00000?00?0000?1100-----------------------1020102100000111
1200-0101031001000100010100000020114-?0-011100100000000200-----------------------
Ornithomimus
???1??210001??11???0???0?000???????0????11??1?000000?0-1110?0000001??000???0?00110
1011??????????00?11?110???0?000??00?0??111?010100001000?011?1?111?0???000011-????1
?????2??-????010???20100011?1????010?00??0?00??0?501?00?10???0??0??0?????000101????
??21111?01?010020????????1000?1??0?00?110?00011?0??????1010000?01010???0001??10010
00000-110????00?00011010?0?????????0100??01???00???00?010?0?000?01100-------------------
----112?0020000?0?0001?0-0201031002000100000000??0020104-00-0000?0?0000??10200-------
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Pelecanimimus
0?????2?00?0??00????????????0???????0????????110??????0-?110????0?????00????????????????
??????????0??????????1???????????????????????0?0000?0?1?????0??????10?103?0?102--210??
0?1?20???0???0???002?????????
?????????????1?00?1????00????????????????????????0???????????????????????0??????????????
??11?0-----------------------102??0200???0?000
??0-010113??0200?????000????01?104??0-00?????000???101?0-----------------------
Shenzhousaurus
???000210000?0001?1?1??0?010????0??0????1?????????00?0-???????00?0?????0?????001???0
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01-?0?????????0???????????????0??????0?0???4????0??0?0?0?????????1?0??????????????????
?????????????????????????????010??0010?1??????101??00?01010???0001?0000?000000-???1?
??00?0001?010???011?0-----------------------1??????????
?????????-010113??000?0????10?00?0010104??0-011??0110000?10100-----------------------
Struthiomimus
???10021000?1?10?1101100000001000000000010011??10?0000010-1?10000000110?0000-001001
112011???1?0???1?0????110???0?000?????01??11?010100011000?011?1?10120???010011-???

?1?????2????????10??020100011??????010000??0?000???501?00?10?0?0??0??1???1?000101??
????21111?01?010020????????1000?1??0?00?11??00011?0??????1010000?010000??000100100
1000000-110????00?00011010?0?????????0100??11???001?-00?01010?00?001100----------------
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Compsognathidae

Compsognathus
0??001000???1010?1?0??201000?00?00??0000??000000000010-??10110???000?001000??????
0?????????????0?????1?????????????00?????????????00000010010-0?000?1210?1-?1010010011
020000000010??1??00?00111?00?????10001??110?023????0?00?0?00?1000001001010 0???1?
??0001010?000000?1???????0?0000?????010100??0???0?0?1???????00?011??01000010000010
000?0-?1?????0000?1???1??0??????0??0?0001??10?0000200?000?0200??00100-------------------
----102??101000???1012?1-010113?0000000???0000?10010104-00-0110???0000??????0-----------------------

Huaxiagnathus
???0000001?010100??0??2000?????000???1??????10000?00????1???1?????0??00?????????????
????????????0????????????????????????????????????00000010????????????????1??10??0?00110?0
00000?00????2?????10????????????10?01???10?01????????0?0?????110??100001000??10??000
10100000000?????????1?00?0??010010100010???0?0?1??02??000?111?????000100000100000
0-?1?????0?????????????????????00???00?20110?000020??00??0200??000?0-----------------------10
2??1?1000?0?1112?1-000113??000001???1010?00000104??0-0110???0000?002000-----------------------

Juravenator
00-0000?01?01010?0?0??2?0???01?000000100???0?0000???10-?10-11???00?0?00?0?0000?????
?????????????0?????????????????????????????????????0000010??????0????????1-?100?01001102?
???00????1?????????0????????????1????????0??????????00?0????0?10?0?0000100????????????
11?000??0?1??00?????0000?????01?????????????????10????????????????????????????0????????
??000??1?????????????????????????????????????0????????00?00-----------------------102??1?10??
?0?11???1-000113??0?00?????10????0000104??0?0011???000???02000-----------------------

Sinosauropteryx
1000000001?01??0?0????00000??0?000??0?????????00??00?0-??10????????0??00????0??00012
?10??????????0???????????????0??????????????????00?00?100???????????????1??101001001102
000000000????1??01?10111?10?????10?01??2?0??13??????00?0?0??1110?0111101000??????0
0010100100000?00?00???0?0000??110010100??0???0?0?101020?000?111??1??0001000011?00
0?0-?1??010001??0??01??01??1??00?0?00?201101000020??00?00200??00000---------------------
--10201221001?0?1112?1-110103000000000???1000?10010104-00-00100?100000000100-----------------------

Alvarezsauridae

Alvarezsaurus
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??????????????????????1??1?10?2-001?1??????11???00??????????????????????????????????????1???0
0????1?????????0????00???1???00???00?00?1??0001?11??
???????????11??????????????????????????1??????????????????????????1??????????????????????????

Mononykus
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?????????????????????????100???????????1012?0???????????????????????????????????????2--?1?0?1??
0?????????1?11?0--?101?10101???1?011?0??????11?01?12?1??????????????1??20??002000-?00?0
000300010?1-00011?1?1?1?1?0?????0???????????111??00?2????1??00?00?0??-?????0-?1????12
1?101001?101????1?1??1011??21???0000200102000?000101120-----------------------112112200?

1000101?11-1111????0200?01?0000?????1?1????1-10010?1000?????1???????????????????????
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Patagonykus
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???0?????????????????????
???????2??????????????110????1?0?0?0?322?111?01??20??????????????????????200?-????001
?30?01011100011?0??-1?1?????????10???0200101????0110?111000??????010??0???????1??11
1?00?0011101111?????0?010?010?1?0???????0??????1?011?0----------------------1?2112??0010
00110211-111???????????????????????1???????????????????????1?????????????????????????
Shuvuuia
???0?011000010101?1010200000?000000000001100-1111-10111011001000-100000100010000
00010-??01?120000021101000100110??100010??11012100001000100000100110??0000?1??0
1??02--210011?1?2010?1121111?1110101010100??01?011?0?502??1120111211100200?11100
10?20??002000-1000000030001011-0001100???1?1?010?2-?111????2??111?000?20-2?1??0000
0?0??-?22000-01??11121?1010011??1???1121??1011122110?0000200102000?001101120-------
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Achillesaurus
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???1??1?0??
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Albertonykus
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1??
Parvicursor
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???20-2????????????????????????????1????????1
?1?1?1??1?1???????22?????????????200??0??
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Therizinosauroidea
Alxasaurus
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???21??10010??????????????????????????01?10111?
0121??????0?????????????10000??0??00???4?1??0??0?1????00?2???000001?????????0?????0?
???000?0????011?00?0??1000?110?11101?1??????02??000?2????1????021101?1?220?0-??????
?01??????0?0???????????????????????001?00?000?0?001?10000----------------------1020111100
1011111200-1001031000000100010100?000010?-00-0010001000???????0----------------------
Beipiaosaurus
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??1??1??1???????????????????????????001?1??1???
121?????????1??0??1??10????????
????????01??????????00??1?????????????????????????????0????????????????????1?????00???0?

?????0?????????10?0??0????00?????????????????00?0----------------------102011100010111111
?0-000113??0000?10?0?0?0?00100104??0?0110??????0?010000----------------------
Erlikosaurus
???10010011000?0??10110000011000?0?0????1???10000100?0-?110?1000010000010?0000001
00??0???101210001---00????00?0001000?00??????1?002110100100011?00020100000011-?---0
00021011100111??1????????????????????????
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Falcarius
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11??110???1110001?101?1111111010?001200102411010?10?1?1111100001111101????110?10
010110100??01?00100011100?0101100111011010??100010011010??1110101100?13?03001?2
2?00-010?01000100010010?01?12?20?010000101101000010??000???00??10000-----------------
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Nothronychus
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?11????2100101?10??????1?1?00?0??200?0??????????????0?????????????????????????????0??1
0??41???10?010000?0??????????????????????????????????12???????????3?101?1?21?00-00???????
???0??????0?????????10???????????????0??????????????00?????????????????????????????????????
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Segnosaurus
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Unenlagia (plus Neuquenraptor per Makovicky et al., 2005)
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Scansoriopterygidae (grouped with Avialae for correspondence matrix construction)
Epidendrosaurus
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Epidexipteryx
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Archaeopteryx
011?10100100??10???0???0?010?0??0??0????11??110?0000?0-1?0-?1000??0??000???0?0?0000
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--?10012?00011?????01??0?1?????????00???0?????0?4????0?20?1?1??1??2???1?11000?1??01?
1010-?10?11111020????001?0??0?11?10?002??1001?1?0????0201100?2?1?11??00131000010?
2101001?????11?111000?0?0????????00?00??0????11?0?00?00??0?01??00000--------------------
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Confuciusornis
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1????2??1?10???0?1????????01??1??20???11?0?01?10??0?00??000?0----------------------1?2??1
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Gallus
011010210?00??????101????????0??0000?100??0201111?000?1110-100?01?????01?00100?0??
?1??????012??101----0???????100?101??0?1????????????????????????????????????11-----1-----2-
-------11011200111111?0?10111100001101?101701110031?-???????????????001?2111103010-
10011011111010111101110011?1?1101012-00101?01???0210111?30-2--2?10031201011?211??
?1101112--11101010?110121?11???111???101110020011??01?001002--0----------------------10
2?1121000001010200-0211121000000000000000000-3--101-00?011?00?00?000----0---------------
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I-II-III matrix

Taxon groups used to construct correspondence matrices are indicated in bold. Some taxon groups are necessarily paraphyletic and thus no formal redefinitions of clades are implied.

Outgroups
Marasuchus ???
???????????????????????????0000?00??0??001???0?00?0??0????????????????????????????????
?????????????0?????????00000?00?000???00?00??1??0?0?0?00?20000?0?0??0?0??0000000000
0??????????0????01?00?????10?0????????0???????000002??00?00000000?0?000000???000000
11?4?00?20000?0?000002?010000000000?00??000000000100000000?0000000?01?????????????
???
???????????????????????????
Staurikosaurus ??
???0???????0??0?????????????????
?????0?????0??????????0?10????0???00000??0??1??00??0000002???0??0?0000000?0?????????
??000?0???????000100?????????10??0??0??1????00?
????0?????000??0?00?0000??0?00?0?00??
???
??????????????
Euparkeria ???0000?0?000???00?0?000000000000000000001??00000000000?0?1000??0
??00?00?0?000?00?0000?0?0?0?0?000?0???0??00??0?0?001?0?000????????0030?01?0??000?1
0200?0?10?001?00000100000?0???0?0000?000???0???00?000?0??0??00??0010?00????????0??
???????????0?????0???0??0?00?00?????10?0????0???0???????000?0???????00??00?????00??0?
??00110010???00?0?0?0???0?0???????0?0000??0?00?????????0???0?0??0?0????0???0?0??????
??0??????????????????????????????
?????????????????????????????????
Eoraptor ???0000?00?00???00?0?01010000100000000001?01001000010?001001?0?
?000?00???0000000?0?10???0???0000?????????????????????????????????00?000100??0??0???
?????00?001000000110?0?000??0???01??0????0??????00??0??0???0???0?1?????????0?0??0???
0??00?????????????0????0??00?0???10?0????????0???????000?0??????000?000?????????0???00
00?01????00?0???0?????0??????0??0?0??????0???0?????????????????0????0?????????0??1?2???
??1??????110???0??1?3????????1?????????10??1?4????0?0?0?1?0?????0??1?1????????????????
?????1?0??????????????????10??
Herrerasaurus ???000?????10???0???010000000000?00?00001?220000000000?0010000???
??0?00?0?001????01?11??000?0?000?0???0??000???1??0??0????0???????0?2?????0??000?????
???????1010?00?0??00?0?000???0101000????0???000001?0??1??00?00000002???0??0?000?00
000?00?????????????0??0?01010?00??100000??0??00????0??000?0???00?0000000?????00??10?
?0000?011???00?0?1?0???01000??0?00?00000?0000?0?10????0010000??0?0?00?0?000?0?000?
0102100010000011111100?0001031000000100001100030001141000000100000100020001011 0
001010100000000????100?01?101010102????????
Zupaysaurus ??????[01]?????0????10??00?????01??0?0?0???0?2?1????0?1?0??01000???
???0000?0?0010?0?0??10????????0?????????????????0??0?????????????????10??????0011??0??
???????????????0??1????????0?0??
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?????????????????????????????????????0??????1011000??????????????????????????????????????
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??????????????????
Dilophosaurus ???010?1???00???01????0000?00011?00???101?22000?00?01??0010?0????0
?0001?0??11????00011????????000?0???1??000?1?1?00??0??101???????0?????0?0???01??????
???0??1010?00?0??10?1?000???0202010????101?000?1100??11?01?00023000???0??0?010?000

001????0?????????0??0?01?00?0???100000??0???0???01?01???0???0??0000010?????10??0???
1??00?10???10?????0???11000010?00?000???0?11?0?10????0010000??0?1?0??0?0?200100???
10200001000001111 10??0101031000000100010100?3010114?0000010000101 00?00101010000
001010000000?????100002?10?000102????????

Coelophysoidea

Coelophysis ???011?????00????????000101001?1?00?00101???000?000010?00100?????
0?0?01?0?0?0?????0?????0?????000?0???1????0??????0??0????????????0?2???0?0??000??????
???1??1010?10?0??00???000???0101??0????1000?0000??0??00?0[01]?00023?01???0??0?01010
0?00?00????????????0????01?00?0???10000???0???0????1?010000???10?0000010????000??0?
??00110110???10?0?0?0???11000??0?00?000???0?11?0?11????0010000????1????0???100???0?
0102?0001000?001111?0?000103?000000100?1110?00000114?0000011000??10?00010101000
011100010000?0????100000?1010?0?020???????

Lophostropheus ??
???
???????????????????????1?00????100??100?10???????[01]???02?000????????010???0?0???????
??1????????????00010??????????????0???????????
???0?????????????????????????????????????
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Segisaurus ??
???
???0????0?????0????????
1???0?????1?00?0???1???0????????????????????????1??????????????????0????010??1?????0?0?
??0?????0?????????1?????0??1???11?????????????0?1????0???100??0???????????????????????
???0??????????????????????????????????????
????????????

Syntarsus ????11?????00???0???000010100111?00?00101?1[01]000?000010?0010010
?????0000?0?010????00010??00??1?000?0???1??100?0?1?00??0??001???????0?2???1?0??000?
???????????1010?10?0??00?1?000???0?010?0????100?00?00100??0??01?00023011???0??0?01
0?00000100????????????0??0?01000?0???100000??0???0????1??10000???10?0000010????000?
?0???00110100???10?0?0?0???11000??0?00?10000?[01]011?0?11???10010000?10?1?0??0???1
001?00?0102?01010000000111110??0001031000000100011100?0000114100000100001 0100?000
0101?000001010000000????????????????????????????

Ceratosauria

Abelisaurus ???1001?0010????0??0??1000?00000?1??0101??????00??2?????1??11?0000
01?111111100001?100?????????100???
???????1???
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??????????????

Carnotaurus ???1000?00100???0??0?01000100000?1000111??2000000?0000??10?11000
0001?1110110000010000????0????100??2??????0???00??101??????????????01000100100??0?
110100000110100??0???1?00?00?00?011200?0?20101?10100100111?1100?00140??1???????00
0???????????000??00?0?0000?0001010?2?01?0?0000?0010?100?010000??????000??00??0?000
0010??10000010?00?0?10000???000?0000?01?101??00?11?????????????????????????????????
?????1????????????0???????????1????????????????????????1?????????0???????????????1?????????
??????????????0???????????????????????

Ceratosaurus ???1001000100???00?0?01000000000?11?010111011000002110?001001000
0000011111101000101 00?0?00?0??100?02??1??000???1??1??0???0????????0?????1?0??0?0???
??100????100??00?0??10?0??0????0212?00000?101100000100011011 10?0014001?0?00?0?010

?020001000?000???????0000?0101000???100010??0???0??1????10000???0??00000001000000
000?101001001000010?10000?0?11000000100?1010001?11?00100???0010011?????????0?????
????2??102???010?????000100??0?10[1234]??0000?1000111???????11?1000001000111??????
?10[1234]?00?0010101000000????0????????????????????????
Elaphrosaurus ??
???0??????????????????????????
???????????????????????0?10????10??10000101??0??00??0024011??????0?000?010?0?????????
??????0????0???0?0???11?01???????????????12100???10?0000000?????1????????0?00010???1
0?1?0?0???11000?00?00?1?1?0?0011?2?10????0?1?011?????????0?????0????????????????????
???1???
??????????????????
Limusaurus ???11?1?011?1?1?00?0??2?0???000000000?00??01?0?0000110??0100?????
000000?1??0000???20??????????000??????????????????????????????????1210?1100?0?10?0?0
????00?11?????????????????????0?00??00?0?101?1??00??00?1??????????????????0?0?0???01000
011?0000?1001??000100101000010?0?11?0?1000[01]010????0000110?1??0100000100100?01
0?0?000?00??00?0?10?00?1???00010???00???0?????????1??????1?????000??0??0????2?0??02?
01000010101000?020???????1121000000100011000030211[23]?0000001000000????021100?
00?111000?020???????0????????????????????????
Majungasaurus ???1001?00100????100001000100000?110010111220000101?0?010?1100
00001?111111000010100?0000001?100012??1000001???????????????????????????1?????????
????????????10?????????????000???????0????2?????????0??????????????????????????????????????
?1?????????????????0????????0????0??0???????????????????????10?????????????000??????????0
??0????????0????????????????????00??1??????????????1??????0???00????0??????2?????????????
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Masiakasaurus ????????????0????100??000???00??????0?????????????????????0???????????
??01210010???????????0??????
???????0010?00?0??0001???0??00?2?101??0100100010?01????01????1??1????01?0??0?0?????
0?????????0001000010???10?1001???11100000?????
?????????????0100000100000010?01011?10?????1??1111100???00?0?0??????????????????????
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?????????????????????
Noasaurus ????????????0????1????1?????0100??????????????????????????????????????
????????????????0???
???????0????????????????2??????2?1[01]1???10??
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???0??
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Ilokelesia ??101?
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????????????????????????2?[01]00?2?101???10?11???1?11???????????????????0???02?0?000?????
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Basal tetanura

Acrocanthosaurus ????000?????1?0??10??10?????00000?1?1???112?1????011?0??1110?????0?
1?11?0?1010?0?0??1?20?0??1?0???????10?0????010?1??01???1?????????00??????011???0?0??
???????1??00?0??2?????????0?1?12?010?0?1012??10?11?00??01???1???????????????0???10?1?1
0?0??0?????????0????11?10?0?00?0??0???00??0???0?0????????????????0???????????01??0?[01]

0??0???0?11?00?00???0?01?100??0?1???????1?????????0??1????000000??0?0??2?000?0?0102
01101000001111200????1131000000100011100002???104?00?0011101000000???0???????????
????????????0??????????????????????
Carcharodontosaurus ????????????0?????0???1?????00??0?1?1???1?2?1?????11?0??111??????0
?1?11?0?1?????????10?????????????????????????1?????0????1??????????????????????????????
???????????0??2???????????????110?0?1?11??10??
???10??????????????????????0?1??????????
??????????01?1?100??0???
??
???????????????
Giganotosaurus ????????????0????10???1?????00000?1?1?????2???????11?0???110?????0?1
011?0?1??????0??10[12]???????????????????????10?1???????1???0??????0????????11???????
???????1??00?0??2?????????0?1?12?[01]1??0?101???10?110??1??1?????????0???0????0???000?
?1?00???????????0?????1?10?0????????????????????????100?10?0??00?010?11?????001??011
0??0?????11?0???????0101?100??1?1?????1?12?0?100????1?????????????????????????????????
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???????????????????????????
Mapusaurus ????????????0????10???1?????0000??1?????1?2?1?????11????1110?????0?
1??1???????????1??10???0??????0?1???0?01?1?
???????????0???????????0?1??2?010?0?1012??10?110001?????????????????????0???1001??0??
????????????????11??0???0?????1????????????????100?10???????01??110????00?????????????
0?1??00?00???0?01?100??1?1?????1??2?0?100???1?1011??0??????0?0???????0?????????????
??
????????????????????
Baryonyx ????101???????????1???2?????00001???0?????2???????11?0??0100?????0
?0001???1??????0??10?????????????????100?????000?1??00???1???0?????00???????1??????01?
1??????3???1?1???????????2?1?120110?0?111???10?110001?01???1???????????????0?????????
0????0????????0????01??0?0?00?02?1???00??1???????????????0?????010?????????00??0?????
0???0?10????00???0101????????0????????????100??0????????????????????????00???????????
??
???????????????????????
Irritator ??????1?????0????????12?????00??1???0???0?2??????011?0??01001????0?0?
01?0?101???????10????????0???????100?????000?1??00???1???0?????????????01??????0?????
??????????1??2???
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??0???????????????????????
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???????????
Suchomimus ????10[01]?????0?????1??12?????0000????0????????????0???0???100????
???00???0????????????10????????0?????????????????????????????????????00???????1?????????
???????3??01?1??2?????????2?1?12?????0?11???????110001?01???1????????????????????????
?0??0?????????0????0?????0000?02?1???00??1????????100???????00???????0?0???00??0?[12]0
??0???0?1??00??0???0101?100??0?0?????1?12???100????1101????????????????????00??1????
????????????????1001????????????????????00?1????????????????????00?0???????????????????
????0????????????????????????
Condorraptor ???
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???????????????????????2?100?0?111???10?11??????????1?????0????????0???0200?1????????
??0????????000?????????0???0?00??????0?1???
???0??????????????0?1?????1?02?????????????????0????????0??????????????????????????????

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????????????
Cryolophosaurus ????????????????????????????????0?0?1???0?2??????011?0??01000????0?0
001?0?1010?0?0??10?0?0????????????????????010?1??00???????0?????????????0110??0??????
???????????0??[12]????????????????00?0?111[01]?????110??1?10?????????0????????????00?0
?0?00??0?????????????????????????0??????00?????????????????????00??0??10?????00?????0??
?????0????00??????0100?010??0?1??????????0??????0011000??????????????????????????????
???
?????????????????????????
Dubreuillosaurus ????10[01]?????0????10???2?????0000????????102??????0???0???1100????0?
0101?0??010?0??????20??????0???????10?0????000?1??00???????0??????0??????????????01?1
??????1??00?0??2????????0????????????111???????????1?0????1?????0????????0???100???0?0
???????????[01]?????0?10?0????????????0??
??????????????010??10?????[01]?????????????00???????????????????????2????0?????????????
???
??????????????????????
Eustreptospondylus ????1?1?????0????10???2?????00????????????????????01?0???1101????0?
0101?????10?0?0??10????????0???????10?0?????0??1??00???1??????????????????????????0???
??????1??00?0??2????????0?0?02?11??0?1111??10?110??1?00???0??????????????0???00?????
?????????????????????10???00?0??1??????????????????????0??00?010?11?????001????10??0
?????0???????????101?100??0?1?????1?12?0?100???111011????????????????0???????????????
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???????????????????????
Afrovenator ????????????101001????2001000?0????????0???10?????11??00??????????
0101?????1??????0??????????0?0??
??????????0??20???0?????0202?11????111?0010?10???????[01]???01??????????0?????100?010
?????????????????????????????0?00????????????1??1?0?0???00?0000100?????00??0???1??000
10???1100?0?0?????010?01?00???10???????0??0????0???111??0?2????0???2????0???1020?211
00000011120??1001131?000001000101????0001????????????????????210???????????????????
?????????????????????????????
Allosaurus ???0?0100101?0000?000?10?010?0??0??0????11??00000111?0??11001000?
00??010???0?00010001120?00010??001001100?0011000??011001?10?000000000010010?1?0
0000101010010200000010200000000010212001000011100010110000100110010030000?00?
0?011010010101000?1??10??0001011000000000000000000100000??01001110000000?0000100
100000000100?1100001000011000000?00010100010001101000101 2?0?10000001101110?0020
00000?02000000000102011110000000111200?10011310000001000111000200010 4?10?0010001
00000000000???????????????????????0??????????????????????
Monolophosaurus ???0001001011 0000?00012000100000?1111010002210100021 10?0010000
00?000?01100001?00001010????????000?????1??00???010?10?010?????????000000100101??
??000211?10110100000010200000000011112??10?0?111?101001000?1011100101300??0?????
?010????????????0???1000000100?0000100100000
0000?1010010010?01?0?000?0??
???
???????????????????????????????????
Neovenator ???010??????10000???0?2000100000?0??1??0??????????????????????????
??0?????1??????????????????
??020????0???0???00???????????????1?????????????????2?????????????????0?????0???0?????
???1???????????????1????????????1????[12]0???1????
?101????????10?0?01??0?1?100????????????????1??????????00?0?0???000?????????????????
???
??????????????????

Piatnitzkysaurus ????????????1?????????100????0?0????????????????????????????0???????????
?????????????????????????????1??0?????1??1??0???01???????0???????????????????????????
?????0???0?0???????1202?10????1110?0100100??1??01??101?0?0????????0????????????????
??????0????01?00?0???10?00???0???0???????1?0?????????000000?????????1????000?01????1
0?0???0???11000?01?00???10??1?12?0??0????????????????????0???????????????????????????
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?????????????????

Sinraptor ???000000000100000000100001100000010100000200000011110??1100110
0?000?011000010000000113000001000000000110000001?000?100100??10?000?0000000100100
10000?010100011010000001000000000000102120010000111010101100001?01000101300?00??
0?0?000???????????00??1???00?????100100?0??????????????????????11101??000?0?00000100
00000011?111000010000?1000000?00010?0001100010100010012?000?0000001001100002000
00?0100?000101?????????????????????001??1010000100010 1???????10?00000011001001????
???10?000?1010001000???????0????????????????????????

Torvosaurus ???010??????0?????????200????000????????1?2?100???011??00??????????
?100??????????0?0?0???0???????????????????????
???00?????0???0????????????2?11????111000100100??1???2??101??????????0?011??0?0?1???
??????????????0????????????0?01???0???1???????120?0???00?0000100?????00??0???0000001
0???00?0?0?0??????????????????????1?12?0??0????01?0111?????????0????????0??010?0?1100
00000111???????11?10100001000111???????10??01?0011000101???????????????????????????
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Basal coelurosauria

Coelurus ???
???
???????????????????????1?10000?111?1011110000000111000 1????????0???1110010?0???????
??????????????00?00??0110?00?0100??00???1?0???????????????????????????111011010??????
??????????1010?000110001?10?????2?2?100100??1111????????????0?0??????????1????????????
?????00????1?3?00000?10001000000???1?3???0???????????00????10?00011010?0?000???????
????????????????????????

Nqwebasaurus ??????????????????101?2?0??0??????????????????????????110110?1?001??
0??01000??????????????????????????????????10010??1????0??????????????????????????????????
???1??????02??20??121???????11200?1?0????0111?????????????0??????????????????????????0
?0?????????00011110000??0?100?0??1????00010??0????????????????????????????1010???00??
???????????????????????????0010?01?12?201?0?00020110?0000200?0000??000101?01020101
0000000111101?110113?000000100010100000101 04?00?001100?10100020100??????????????
?????????0???????????????????????

Ornitholestes ???0000?010?10100?10??1000??11000??00??01?000000010010??0101?000?1
0?00001000?000100011[23]??????00000??0????0?0??101?1?0?00??11?????000000010000 1110
00101000100101011100102000000000???2?20001?111?1011111001010110?101?0?010?10?0
?01110?0?0??1?1??????????????????????01010000001100?00??????111?000000?00011011000
00011??10?100001?01001?00000?0????????????1?0010??????????0???????????00???0?1000?0?
0?1?0000????????????0???????????113?0000000000???00?0??0104?00?0010?0????00?1?00???
??

Tanycolagreus ???100?00?00????????????????????00???????????????000110?0?????????0??
011??????????00010??1000???101??
???01???10????????0??????????????????????????11100?001???001?0???????????00???0???????
00????????00010110000??0110?01?01000000???110???????????????????????????111?1???0???
?????????????10?0100011000101 0?01?12?20100100?201111000010?0000002001?0000102010
11000001010200?1001131000000100010?0002000104000?0010100100????000???????????????
?????????????????????????????????

Tugulusaurus ???
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??0?????????0??????????????
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???0100010???0?101??01?12?0?????002[01]11101??????????????????0???1?20111?0?0000111
21???00??
????????????????

Tyrannosauroidea

Albertosaurus ???1?0000011?0????101????????00011?00???002??0000011?????1??0?0??00
??111???0?010010?10???????0??0??????0???01?000??01?010?10?1?000000000010010?1?01100
???010?10??0?10010?000000000102?20000000????????010000?00??00?0?410?00?10?0?0??0?
?0?????00000100?01000010?00?00001001??????1000?0?10000?110?00000?0?10???1000000?0
10001??000100000102000?1???01001100000?0001?12?20100100?20110?00002000010?0?00
??00??1?2??1110?0000111??0?0?01?3??0200?10?0101???00??1?0??0?1010???020???????0????
???????????????????0????????????????????????

Daspletosaurus ?????01?0??1?010???0?10000001?0011100?????2?000?00111???011??1????
????1??????????10?103?????????0?????????0????????????10?10?01000?????????1?1???????21
1????1??0????????????00000??????????0??111
1??????????????1????????????01????????????????????????????????10?????????????????????????
???????????????010002????1010?01?12?2???????????????????????????????????01?2??1?10?00
?0111????0??1?3??0200?10?0101???00??1?0??0?1010???020???????0???????????????????????
0???????????????????????

Dilong
10?1000?011?10100110?1000?0001001010000001221000010110?0010001000000000120001?1
0010011??0?????00001001100000???1??1?100??0????????000000100001111111010101?1101?
001001020000000000????1?00??0?1?1??0100?????1?????0101?????????????0????1?001????000?
??????0????01000?01??10001????????????????1?1?00000??0?10100100?0?0??11?????????0????
?0??0????11?110001?00??010001?12?201???00020111??0????0?00?0?2?0??000?1?2??1010?00
?011?2???00?1?3??0000?10?010????000?1?4??000010???000???120?????????????????????????
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Guanlong ???1000001111010011 0?10?0???0100101?0000012210100101 1??0?100010
00010000100001010?100??30??????000010001000001100011000010010112000000000100001
11??1?0????10?1010001011020?0000?0?????1?000000111010100100011001000101300010?10
?0?010??1000?11??000???????000101?0000??1110000001000000?101001111000000?0010101
10010??0110001000001000001?00000?0?1?0100011000101 0?01?12?201001000101101000020
0000000210??0??0102??1110000000111200?100113?000000100010000020 00104?00000100001
00000000?100001?1110000020???????0???????????????????????

Tyrannosaurus ???1000000111010111011000000000001110010?0022100000111 0??1111010
00001?11122?010100100103?0000100000100111 0?00100001101?01?010?020000000000100101
1?0110010101011010001001020000000000102120000000001111?0100100001001100000310?00?
10?0?0?0001001111000001??11??00010100000001001001?00100010?1?0?01111100000?0110
1011000000101000110000100000102100 0?10110100120001101000101 2?20??0100020110100
0020000100020000000001020011100000001112 00?000113100200010001010000000 1?0?00?101
0?0?02????????0????????????????????????0????????????????????????

Stokesosaurus_clevelandi ???
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???111?000101?1?1110110010??10??????????????
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Stokesosaurus_langhami ???
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Ornithomimidae

Anserimimus ???
???????????????????????????0???1
???0??????????????????????????????????????0??????
?????1110??1?0???2??????????????1??0?00?110?00?11?0??????1010000?010?00??00?1001001
0??000???????????0?????????????????????????????00???00?010???0???011??????????????????
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Archaeornithomimus ???
????????????1??0??1???1??????????
??????????????1???????????1?20?1100????011010000??0?00????311010?10?0?01?00?000???0
??????????2011110??000?201??01?00100000?????0100000010?0000100100010??01000?200
000101000010001??10?010001?01?0010?01?02?????1000??1010?0000?00?110?0?0????11????
??????????????1?1??10??????????????????????1??????????1?????????????1???????????????????
??????????????????????????????

Gallimimus ???1002100010010??101100?000?00000000000110??000000010?01100000
00010?0000000?00111200????1?010?100?1101000010?0001100001??11?01010000100000011?1
?10020???000011?????1?????2????????10?1?20101011??????010000??0??00???501??0?10?0?0
??0??0?????00010???????21110?01?010020?0????001000?1??0??01110?00011?0?0????101000
0?010100??0001001001000000?110????00?000110??00?????????0100??01???001??00?01010?
00??01101020?010000?0?0001?0?01011310010000???0000??0010104??0?0010?010000??1010
0???????????????????????0???????????????????????

Garudimimus ???1002?00011001?01011000001000?0100000??01010000010?01100?0
00?0?0?00?0?001000??0?113??1?0100100?11???00010100011000?1????????00101000000101
?10020??????011?????1?????2???????00?10???????????????01?00?0???0?0101401?1?????????
??0??1?10000111?01000001001000?01
00011000??0?????0???????10?010001??011011001?10??00??100?20????0000200?000?02000??
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Harpymimus ??????2?0??????0???0???0?00?????????????????1????????0?????????????
???0??????????????????????????0??????????????????????????????????????0?10?0???1???0?0000?0?
10011??????2???01????0?0???????????????????????????0????????4????????????????????????
???????????????????????2??0????001?00?1??0?00111????????0???????????00?????????00??0?
1????00??001??00000?00?0000?11010201021000
001111200?01010310010001000101000002011 4??0?011100100000000200??????????????????
????0????????????????????????

Ornithomimus ???1??210001??11???0???0?000???????0????11??1?000000?0?1110?00000
01??000???0?001101011??????????00?11?110???0?000??00?0??111?010100001000?011?1?111
?0???000011?????1?????2???????010???20100011?1????010?00??0?00??0?501?00?10???0??0?
?0?????000101??????21111?01?010020????????1000?1??0?00?110?00011?0??????1010000?01
010???0001??1001000000?110????00?00011010?0?????????0100??01???00???00?010?0?000?0
110112?0020000?0?0001?0?0201031002000100000000??0020104?00?0000?0?0000??10200????
???????????????????0???????????????????????

Pelecanimimus
0?????2?00?0??00???????????0???????0????????110??????0??110????0?????00???????????????
??????????0??????????1???????????????????????0?0000?0?1?????0??????10?103?0?102??210?
?0?1?20???0???0???002????????
??????????????1?00?1????00??????????????????????0???????????????????????0?????????????
??11?102??0200???0?000??0?010113??0200
?????000????01?104??0?00?????000???101?0???????????????????????0??????????????????????
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Shenzhousaurus ???000210000?0001?1?1??0?010????0??0????1?????????00?0????????00?0
?????0?????001???0????????1????????????????????????????????????000100000?1?1?????0???
?10??1?????12???0101??0?????????0???????????????0??????0?0???4????0??0?0?0??????????1?
0???010??0010?1??????101??00?01010???0001
?0000?000000????1???00?0001?010??011?1?????????
??????????010113??000?0????10?00?0010104??0?011??0110000?10100????????????????????
???0????????????????????????
Struthiomimus ???10021000?1?10?1101100000010000000010011??10?0000010?1?100000
00110?0000?001001112011???1?0???1?0????110???0?000?????01??11?010100011000?011?1?
10120???010011?????1?????2????????10??020100011??????010000??0?000???501?00?10?0?0?
?0??1???1?000101??????21111?01?010020????????1000?1??0?00?11??00011?0??????1010000
?010000??000100100100000?110????00?00011010?0?????????0100??11???001??00?01010?0
0?00110102000200000000000100?01011300020000000000000000020104?1020000101000000102
00????????????????????????0????????????????????????

Compsognathidae

Compsognathus
0??001000???1010?1?0??201000?00?00??0000??000000000010???10110???000?001000??????
?0??????????????0?????1?????????????00?????????????0000010010?0?000?1210?1??101001001
10200000000010??1??00?00111?00?????10001??110?023????0?00?0?00?10000010010100???1
???0001010?000000?1???????0?0000?????010100??0???0?0?1???????00?011??0100001000001
0000?0??1?????0000?1???1??0??????0??0?0001??10?0000200?000?0200??0010102??101000??
?1012?1?010113?0000000???0000?10010104?00?0110???0000??????0????????????????????????
0????????????????????????
Huaxiagnathus ???0000001?010100??0??2000?????000???1??????10000?00????1???1?????
0??00???????????????????????????0???????????????????????????????????00000010??????????????
?1??10??0?00110?000000?00????2?????10???????????10?01???10?01????????0?0?????110??10
0001000??10??00010100000000?????????1?00?0??010010100010???0?0?1??02??000?111?????
00010000010000000??1?????0??????????????????00???00?20110?000020??00??0200??000?102
??1?1000?0?1112?1?000113??000001???1010?00000104??0?0110???0000?002000????????????
???????????0????????????????????????
Juravenator
00?0000?01?01010?0?0??2?0???01?000000100???0?0000???10??10?11???00?0?00?0?0000????
??????????????0????????????????????????????????????0000010??????0????????1??100?0100110
2????00????1?????????0???????????1????????0??????????00?0????0?10?0?0000100??????????
??11?000??0?1??00?????0000?????01??????????????????10????????????????????????????0??????
????000??1??????????????????????????????????????0????????00?0102??1?10???0?11???1?00011
3??0?00?????10????0000104??0?0011???000???02000???????????????????????0???????????????
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Sinosauropteryx
1000000001?01??0?0????00000??0?000??0?????????00??00?0???10???????0??00????0??00012
?10??????????0??????????????0???????????????????00?00?100???????????????1??101001001102
000000000????1??01?10111?10?????10?01??2?0??13??????00?0?0??1110?0111101000??????0
0010100100000?00?00???0?0000??110010100??0???0?0?101020?000?111??1??0001000011?00

0?0??1??010001??0??01??01??1??00?0?00?201101000020??00?00200??000010201221001?0?1
112?1?11010300000000???1000?10010104?00?00100?100000000100??????????????????????0
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Alvarezsauridae

Alvarezsaurus ??
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????????????????????????0??1?11??????????????????0?????2??11?01?02?11??2???1?????????
?????0????0??00?????????????????????1??1?10?2?001?1??????11???00?????????????????????
???????????1???00????1????????0????00???1???00???00?00?1??0001?11????????????????????
???11???????????????????????1???????????????????????1????????????????????????????????????
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Mononykus ???
???100??????????1012?0??????????????????????????
?????????2???1?0?1??0????????1?11?0???101?10101???1?011?0??????11?01?12?1???????????
?1??20??002000??00?0000300010?1?00011?1?1?1?1?0?????0??????????111??00?2????1??00?0
0?0????????0??1????121?101001?101????1?1??1011??21???0000200102000?00010112112112
200?1000101?11?1111????0200?01?0000?????1?1????1?10010?1000?????1??????????????????
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Patagonykus ??
???0????
?????????????????????????2???????????????110????1?0?0?0?322?111?01??20?????????????????
?????200??????001?30?01011100011?0???1?1?????????10???0200101????0110?111000??????0
10??0???????1??111?00?0011101111?????0?010?010?1?0???????0??????1?011?1?2112??00100
0110211?111?????????????????????1???????????????????????1????????????????????????????
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Shuvuuia ???0?011000010101?1010200000?000000000001100?1111?101110110010
00?1000001000100000001O???01?12000002110100010011O??100010??1101210000100010000
01001110??0000?1??01??02??210011?1?2010?1121111?11101010101OO??01?011?0?502??112
0111211100200?1110010?20??002000?1000000030001011?0001100???1?1?010?2??111????2?
?111?000?20?2?1??00000?0????22000?01??11121?1010011??1???1121??1011122110?0000200
102000?001101121?2??2200?1000101211?1111?3??0200?01?0000???301?1????1?10?10?1000?
???01??

Achillesaurus ??
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???1??1?0??????????????????????
???2??111????2???????????????????????????????????
???0?????????????????????????????????????
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Albertonykus ??
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???????????????????????????1?????????????????????????2?????????1?21?????????????????1???1
1??
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Parvicursor ??
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??0??????10??1????????1???1?1????????????????????
??20?2????????????????????
???????1????????1?1?1?1??1?1???????22??????????????200??0??????????????????????????????

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Therizinosauroidea
Alxasaurus ??
??21??10010?????????????????
????????01?10111?0121??????0?????????????10000??0??00???4?1??0??0?1????00?2???000001
?????????0?????0????000?0????011?00?0??1000?110?11101?1??????02??000?2????1????0211
01?1?220?0????????01??????0?0???????????????????????001?00?000?0?001?10001020111100
1011111200?1001031000000100010100?000010??00?0010001000???????0??????????????????
????0????????????????????????
Beipiaosaurus ???
???1??1??1????????????????????
?????001?1??1???121?????????1??
0??1??10????????????????01??????????00??1?????????????????????????????0?????????????????
???1?????00???0??????0?????????10?0??0????00?????????????????00?1020111000101111?0
?000113??0000?10?0?0?0?00100104??0?0110??????0?010000???????????????????????0??????
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Erlikosaurus ???10010011000?0??1011000001100?0?0????1???1000010?0??110?10000
10000010?000000100??0???101210001???00????00?0001000?00??????1?00211010010001?00
02010000001??????00002101110011???1????
?????????????????????????????????0???????01??
???0????0??0??????000????????????
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Falcarius ????????????????????0??00?????0
0?????????1?010??????????????1??00?001?000??00?01?11011200??0??0001???????????????
????????0010?10111??110???1110001?101?1111111010?0012001024110?10?1?111110000
1111101????110?10010110100??01?0010001110?010110011101101??10001001101??11101
01100?13?03001?22?00?010?0100010001001?01?12?20?010000101101000010??000???00??1
0001020111000101111020?100113100000010001000?0000104?00?01100000000012000???
?????????????????????0????????????????????????
Nothronychus ??
???????????????????????????????????????0??00??00??0??1?1?110????????????????????????????
??????0000?10?11??11????2100101?10??????1?1?00?0??200?0?????????????0???????????????
??????????????0??10??41???10?010000?0??????????????????????????????12???????????3?101
?1?21?00?00??????????0??????0?????????10??????????????0??????????????00????????????????
?????????????????????????????0??????????????????????????0????????????????????????????????
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Segnosaurus ??
??1??1?01?00?1?000?0???0100
????????000?10111?0111???0??????????????????????
???????1?????????1??00?0????01?????????????110??0201?1??????020?000?210?????00021101
?1?2?001??0?????????????01?0?????????????0??100????001?0??00?10?0?????????????????????
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Oviraptorosauria
Avimimus ????????1?1????????????????????????????????????11?1????????????000??0
??001?????0?0000?11???????????1?1?0110?0001110??00?00?110?????02??????2?100?0?00????
??110?11??????2????2????????11?1?00011?101?001?1100000?010?01?2?01??0??????????????
??????????????????????0????01010?10?001????0???1???01????001?1?0????0211?00?110??02
000121030010?0000?010?111002?100001??01?02?2?10??011201101110?200?01?10100??????

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Caudipteryx_zoui
010???0?111??0000??????0?0?0???????0????1????00001???12?10??1000010??00????0???0?00
0?????????????1???????????????????????????????????212000001?0???0?0????0?0??10???1012???
?2????0?????????0?0?0?1????????????????[01]?0???4????0?21???????0??011110?????0?10??0
0???100??0?0??1??10???1???00???11010101??0?1?1?0?100?????00?????01??201210?00102?0?
0??1???1111110????1????????2??????012011?100?0??0??1??0?00???000102??1010?1???0?02?
0?010113??0000?0????????????1?102??0??11?????????????1?????????????????????????????????
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Chirostenotes ???1?????1?0??????111???
???????????????????????????1?010?01?1?0?110??01?001?11???1??21200000100?0??00?0????1
00???????1?????2???????????????0??1?10??????111?????????????521?????????0??????????????
?????????10?????0?10??????????????????????????010??1?0?????????02??000??120????2012103
001021000?01?????0?????????0?0????????????00???1???0??0?00?010?0?00??100?102??00100?
???10010??000113??00000????1000??10001?4????????????????????0?0??????????????????????
?0???????????????????????
Citipati ???10000101010101?0?1110000020100 0?011?0011?020110000 1112?10?11100
0100?0012000?000000010?0110111111?0??10101001110?000?00??12121000212000 2010010
1000100?0111011?????1?????2????????10?1?20101111??????111000??0??10?1?52???0?11????
??0??2?????00011?01?111100???00?110001??????001?00?0??1?10?010???001?1??????020100
0?110110??20?210300102?000?01????21?10100010?0?????????0000??0????00?0?00?000?0?0
0??100??????????????????????0??00??????????????????????????0???????????????????????????0?????????
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Conchoraptor ??????001110?0?00??1???0?020???????1????1???111?000??12?10??100001
0??001?????0000000?????????1??1?????????0????1??????00??11?????0212000201?0?0?000?0?
??101011?????1?????2???????????????0?????????????1???01??0????????11??0??????1??????????
??0???????1?11?01??0??010001??????001?????????????010?1?001?1??????0210000?1100?1??2
0??1???010??000?0??????11?1010?010?0?????????????0????????0?0?00?00??0?0???100010 2??
1?1000?0?11110??110113??000000?0?10?00?0010104??0?0010?0?00000?00100??????????????
?????????0???????????????????????
Hagryphus ??
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??100010200011000 00011010?
?0001131000000100010000?200?104?00?011010100000?00000???????????????????????0?????
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Incisivosaurus ???1000001111?000?101100000100000011100011000010100110??????01000
100?001??000000012010?01101210?11?0??11110?1?1100010000??????????2110000000 0?0?0?
010??0?10110120?002???11?010011???
??0?????????????????0??????????
??1?????????????????????
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Ingenia ????????1?1?????????????????????????1?????????????????12????????????0??
00??0????????????212?00??100?0?000?0???111
011?????1?????2???5????0??1?????????2?????00???
001?11120010?00??1?000??????001?00?0????10?010???0?1?1?0????02???00?110?11??200210
3001011000?010????11?101?001000?????????0?00?201????000200?00010?0001100?1?2??121

0?10?0111????1001?3??0100?0???000????00?1?4??0?0010???000???200?????????????????????
?????????????????????????????
Microvenator ??
??212?00????????????????????
???????2????2????????11110?0?01?10???01?011000??0?21??11?0??????1???1??0??2?1???????
????????0001??00?0?0?1110??0?00100000??????1010101001??101100020??00??10101??20???
???0?????????1??11101210110 01000???2?2?1000001201101??00??????????????1000?????????
????????2?????0???
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Oviraptor_philoceratops ??????0?11????1????1???0?0?0?0?????1????1???0?10??0??12?????1??
0??0??001????????000?10???1?1?1??11?0?1???????????????0?00???????????21200020100?0?00?
?0????11?11?????1?????2??????????????????????????????0??????????1??????0???????????????
????????????11????????0??1???0??????001????0????1??01?????0??1????????????????????????
?????????????????????????????010?0????????????????????0?????????????????00???????????
?????????0??00??????????????????????0???????????????????????0???????????????????????????
????????????????????????
Oviraptor_mongoliensis ???????01110?0?00??1?????????0?????1????1???0?1?0001?12?0?
???000??0??00????0?00?000??????1???1??1???????0???????0??????????????????2120?0?0100?0
?0?0?0???111011?????1?????2??0??????????
?????????????????11????????0??1?000????????1?????????1??01??11?01?1????????????????????
????????????????????????????????????0???0???????????????????????0????????????0????0???????
?????????????????00?????????????????????????0??????????????????????????0??????????????????????
?????????????????????????????
Dromaeosauridae
Achillobator ???????????????1???0???0???0???
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?????0010?0?0???000????2?20?01??1???????110????1??0?????????????0??????1??2?????11????
??????10110?????0??????????????????????????113?11011?0??????021??000110?01??000100000
1021000??0?????21??110?0??10?????????????0??0????00????0?10?????1???00????????????????
???????0????????????????????????0??????????????????????????0?????????????????????????????????
?????????????????
Adasaurus ???10??????????????
???00??0?0????????????????0?????????????????????????
?0???0002????10???0020???????????????????????????????????40101?????????????1??????????
???????10110100100???????????????????????????11?3?000???10001000211 1??120110010001210
?00102?0?0??1???0????01????????????????????
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??????????????????
Deinonychus ???000200001111 10100?00000000000001010001 10?10000100110?11???1?
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Troodontidae

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Scansoriopterygidae (grouped with Avialae for correspondence matrix construction)
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Confuciusornis
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Gallus
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3010?1001101111101011110111001 1?1?1101012?00101?01???0210111?30?2??2?10031201011
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01010200?02111210000000000000000?3??101?00?011?00?00?000????0?????????????????????
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