

## 1.0 Further discussion of the main phylogenetic analyses

Trees were produced and analysed in TNT 1.5-beta (Goloboff et al. 2008). In total 74 taxa were scored for 457 characters. Using the new technology search function, with ratchet and drift set to their defaults (10 iterations and 10 cycles respectively) and with 100 random additional sequences, our data produced 93 MPTs of length 1734. Bremer supports were also calculated using TNT 1.5-beta.

The following characters were treated as ordered:

24, 35, 39, 60, 68, 71, 117, 145, 167, 169, 174, 180, 197, 199, 206, 214, 215, 222, 251, 269, 272, 286, 289, 303, 305, 307, 313, 322, 333, 334, 338, 353, 360, 376, 378, 387, 393, 442, 446

Our characters were drawn and modified from a number of previous studies and supplemented with an additional 63 novel characters. The main sources of our characters were Gauthier (1986), Sereno (1991), Langer and Benton (2006), Yates (2007), Butler et al. (2008), Ezcurra (2010), Nesbitt (2011) and Pol et al. (2011).

Our investigations and analyses showed that a number of characters previously thought only to appear in theropods or sauropodomorphs (or both) can also be found in several ornithischian taxa and, conversely, a number of features traditionally associated with basal ornithischian taxa are also present in basal theropods and, in some instances, sauropodomorphs. Furthermore, many other characters that are more traditionally associated with only one or two dinosauriform groups were found to have a wider and/or more complex distribution than other studies have previously proposed, e.g. a mediolaterally oriented scar on the anterior face of the distal femur – present in *Dromomeron* (Nesbitt et al. 2009a), is also found in some herrerasaurids (PVSJ 373). We tried, as objectively as possible, to capture all these similarities, as well as notable differences, between the basal members of each of the major dinosaurian lineages using our newly composed set of characters.

Critically, a large number of character states were found to be present in ornithischians and theropods only (see below). Additionally, a number of other character states were found that are present only in sauropodomorphs and herrerasaurids. Some previously proposed dinosaur synapomorphies were also found to be absent from a few important early dinosaur taxa. In most of these cases, our finds changed the optimisations of important characters within the tree, often leading to changes in the structure of the tree itself, as well as our interpretation of the basal dinosaur interrelationships that the distributions of these character states imply.

A number of novel clades were recovered by our analysis. Of these, Ornithoscelida is the most strikingly different from previous systems of grouping and classification. A full list of synapomorphies for each of the major clades that we have recovered is given later in this Supplement (Section 3.4). A discussion of a few of the other important finds of our analysis follows here.

A constraint tree was also produced in TNT 1.5-beta in order to test how many additional steps it would take to recover a strict consensus tree in which a traditional saurischian clade (theropods and sauropodomorphs) was recovered to the exclusion of all ornithischians. To run this analysis, TNT was constrained to recover trees in which the 20 'theropod' taxa (4 herrerasaurids and 16 'other theropods') and 22 sauropodomorph taxa that were looked at in this study in a single, monophyletic

group. The program was set to exclude all other taxa that were looked at in this study from this traditional saurischian clade. The analyses produced a strict consensus tree from the most parsimonious, constrained trees and the length of this tree was compared with the consensus trees of the main analyses. What this analysis showed was that, for a monophyletic clade that contains all the taxa that are traditionally regarded as saurischian to be recovered, an additional 20 steps would be needed. Given that 20 additional steps would be needed to recover a traditional Theropoda+Sauropodomorpha sister-taxon relationship in this analysis, it seems unlikely that this clade is truly monophyletic, contrary to the conclusions of previous studies (e.g. Langer & Benton 2006; Ezcurra 2010; Nesbitt 2011). The result of this study is not affected by the positions of Herrerasauridae and *Eoraptor* within Dinosauria, as the constraint tree did not require any resolution within the clade that excluded all ornithischians and all non-dinosaurian dinosauromorphs.

Bremer supports were calculated in TNT 1.5-beta (Goloboff et al. 2008). Table S1 shows the strict consensus produced with all taxa included and Bremer supports listed for the major nodes. The newly named Ornithoscelida is very well supported, with a Bremer support value of 4. In this analysis Sauropodomorpha and Saurischia (new definitions) have the lowest Bremer support values of the major dinosaurian clades. Further to this, Dinosauria is also poorly supported, with a Bremer support value of 1.

Further investigation of the causes of the decays of Dinosauria, Sauropodomorpha and Saurischia revealed that a few scrappy and often troublesome basal dinosauriform taxa move out of the groups that they are most traditionally associated with, into various positions within Sauropodomorpha and Saurischia, in a small number of the suboptimal trees. Investigation into which characters caused these alternate topologies/assignments revealed that a number of the suboptimal trees resulted simply because of lack of data. For these reasons we then chose to run a further analysis with these taxa excluded *a posteriori*, on the grounds that they could be considered as wildcard taxa.

Without the inclusion of *Saltopus elginensis*, *Agnosphytis cromhallensis*, *Eucoelophysys baldwini* and *Diodorus scytobrachion*, all of which have relatively low levels of skeletal completeness when compared to most other taxa in our study, the Bremer supports for the major groups increase (see Table S3). Critically, Dinosauria, Silesauridae and Dinosauria+Silesauridae were all found to have higher Bremer supports in this analysis. The Bremer supports of Ornithischia, Theropoda, Herrerasauridae and Sauropodomorpha also increased from the initial analysis.

**Table S1**

Node	Bremer support value	
	All taxa included	Some taxa excluded
Dinosauria	1	3
Saurischia	2	4
Ornithoscelida	4	4
Theropoda	3	3
Ornithischia	4	4
Dinosauria+Silesauridae	1	2

Bootstrap frequencies were also calculated, following the exclusion of the problematic taxa using the resampling->Bootstrap option, with traditional search selected and with 100 repetitions, in TNT 1.5-beta (Goloboff et al. 2008).

Extended Data Figure 1 shows the strict consensus tree that was produced from 1674 MPTs, each of length 87 steps, when *Saltopus elginensis*, *Agnosphytis cromhallensis*, *Eucoelophysis baldwini* and *Diodorus scytobrachion* were excluded. Both Bootstrap values and Bremer support values are given for a number of key clades.

### 1.1 Justification for ingroup and outgroup taxon choices and testing the effects of using alternative outgroups

The taxa included in this study were chosen to provide an inclusive sample that represents the full spatial and temporal range of dinosauriforms during the first half of the Mesozoic Era. Well known and ‘exemplar’ members from each dinosaur clade were included (e.g. *Coelophysis bauri*, *Plateosaurus engelhardti* and *Heterodontosaurus tucki*) as well as a number of more poorly known and often overlooked taxa that were found to contribute important anatomical information (e.g. *Panguraptor lufengensis*, *Pantydraco caducus* and *Fruitadens haagarorum*). All taxa that have been consistently recovered as ‘basal’ members of the major dinosaurian lineages were also included (e.g. *Eodromaeus murphi*, *Pisanosaurus mertii* and *Saturnalia tupiniquim*), as well as taxa whose phylogenetic position within Dinosauria has been difficult to determine (e.g. *Eoraptor lunensis* and *Herrerasaurus ischigualastensis*). Many taxa that regularly appear in phylogenetic analyses of the various groups within Dinosauria were also included (e.g. *Zupaysaurus rougieri*, *Massospondylus carinatus* and *Scelidosaurus harrisonii*). A handful of more recently discovered dinosaurian taxa were included to incorporate the large amount of new anatomical information that has been published in recent years (e.g. *Dracoraptor hanigani*, *Pampadromaeus barberenai* and *Laquintasaurua venezuelae*). For the first time, a large sample of ornithischians was included in this early dinosaur dataset. The relatively small number of Triassic and Early Jurassic ornithischians (when compared with the number of sauropodomorphs and theropods from the same time period) required us to include several stratigraphically younger, relatively complete ornithischian taxa, in order to fully capture major aspects of ornithischian diversity (e.g. *Agilisaurus louderbacki* and *Jeholosaurus shangyuanensis*). A handful of derived sauropodomorphs, currently believed to be close the origins of Sauropoda were included (e.g. *Aardonyx celestae* and *Pulanesaura eocollum*), as these taxa are known from Late Triassic and Early Jurassic formations and provide important information about the anatomy of sauropodomorphs. As the dinosaurs’ closest relatives (Langer et al. 2010; Nesbitt 2011), silesaurids also provide critical anatomical information and this study includes all currently known members of Silesauridae. Other dinosauromorphs, such as *Lagerpeton chanarensis* and *Marasuchus lillioensis*, were included in order to maximise the amount of anatomical information on non-dinosaurian dinosauromorphs in this study. In addition to the aforementioned taxa, a small number of more enigmatic taxa were included in order to test whether or not the phylogenetic position of these taxa could be more robustly resolved by this dataset. Taxa like *Saltopus elginensis*, *Agnosphytis cromhallensis* and *Nyasasaurus parringtoni* have all previously been linked with the base of the dinosaurian tree and, as early ‘dinosaur-like’ taxa, they each offer potentially interesting additional anatomical information to that provided by the more frequently studied taxa. Inclusion of these taxa has provided some interesting results (see sections 1.4, 1.6 and 1.7 of this Supplementary Information file) and this may renew interest in them, as well as in the formations from which they have been recovered. Exclusion of these three taxa does not have any effect on the overall tree topologies recovered by our analyses (see below).

For the main analyses presented in this work, the non-archosaurian archosauromorph *Euparkeria capensis* and the rauisuchid pseudosuchian *Postosuchus kirkpatricki* were chosen as non-ornithodiran outgroup taxa. Both of these taxa are fairly complete and therefore can be scored for nearly all of the anatomical characters used in this study. This provides a large amount of information on the states of anatomical characters in non-dinosauromorph archosaurs and helps polarise these characters. Characters for which character state information is lacking in non-dinosaurian dinosauromorphs were polarised using information from these outgroup taxa.

In order to better test the hypothesis forwarded by this study, and to investigate any potential effects that outgroup choice might have upon our results, additional analyses were run using alternative outgroup taxa. Firstly, the early pterosaur *Dimorphodon macronyx* was scored for the 457 characters used in this study and included as an alternative outgroup taxon in an additional analysis (as a well-known and well represented group of non-dinosaurian ornithodirans, Pterosauria has the potential to provide evidence on characters states outside of Dinosauria). The strict consensus trees produced when *Dimorphodon macronyx* was included in the dataset is shown in Extended Data Figure 2. Secondly, the non-dinosaurian dinosauromorph *Silesaurus opolensis* was tested as an alternative outgroup taxon, and the results of this additional analyses is shown in Extended Data Figure 3.

In all of the additional analyses that used alternative outgroup taxa, the fundamental shape of the dinosaurian tree did not differ from that produced in the main analysis presented in this study. This strongly suggests that outgroup choice has no significant role in the recovery of the main results of this study and that the dichotomy within Dinosauria of Ornithoscelida and Sauropodomorpha+Herrerasauridae (Saurischia, new definition) is robust.

## 1.2 Justifications for designating characters as ordered

Characters 24, 35, 39, 60, 68, 71, 117, 145, 167, 169, 174, 180, 197, 199, 206, 214, 215, 222, 251, 269, 272, 286, 289, 303, 305, 307, 313, 322, 333, 334, 338, 353, 360, 376, 378, 387, 393, 442 and 446 were treated as ordered. The rationale for each character that is treated as ordered is as follows:

**24.** Level of the posterior margin of the external naris: 0, anterior to or level with the premaxilla-maxilla suture; 1, posterior to the first maxillary alveolus; 2, posterior to the midlength of the maxillary tooth row and the anterior margin of the antorbital fenestra (Wilson and Sereno, 1998; Yates, 2007; Ezcurra, 2010). ORDERED – This character describes the posterior expansion of the external naris in dinosauriforms. In most taxa that were looked at in this study the external naris is not greatly expanded posteriorly and as a result its posterior border does not extend beyond the premaxilla-maxilla suture. However, in certain taxa the external naris is expanded posteriorly and the posterior margin of the naris is located more posteriorly in the skull. In many taxa that have such an expansion the posterior margin lies posterior to the first maxillary tooth row and in others it lies more posteriorly, beyond the anterior margin of the antorbital fenestra. We order this character as we consider a posteriorly expanded external naris to be homologous regardless of the posterior extent of the expansion beyond the premaxilla-maxilla boundary i.e. character states (1) and (2) are different expressions of the same character state.

**35.** Maxilla, lateral surface: 0, completely smooth; 1, sharp longitudinal ridge present; 2, rounded/bulbous longitudinal ridge present (Gower, 1999; Weinbaum and Hungerbühler, 2007;

Nesbitt, 2011). ORDERED – We order this character to homologise the presence of a ridge on the lateral surface of the maxilla. As this study is attempting to be as objective as possible, we do not feel that it is justifiable to make the assumption that sharp and rounded ridged on the maxilla are entirely different features.

**39.** Antorbital fossa: 0, restricted to the lacrimal; 1, restricted to the lacrimal and dorsal process of the maxilla; 2, present on the lacrimal, dorsal process of the maxilla and the dorsal margin of the posterior process of the maxilla (the ventral border of the antorbital fenestra) (Nesbitt et al., 2009c; Nesbitt, 2011) ORDERED – This character is treated as ordered following Nesbitt (2011).

**60.** Ornamentation on jugal: 0, absent; 1, present as small rugose surface; 2, present as well developed jugal boss (modified from Butler et al., 2008). ORDERED – This character is treated as ordered to homologise the presence of any ornamentation on the jugal.

**68.** Lateral temporal fenestra, maximum anteroposterior length of ventral half: 0, more than twice the maximum anteroposterior length of the dorsal half; 1, less than twice the maximum anteroposterior length of the dorsal half; 2, maximum anteroposterior length of the dorsal half is greater than that of the ventral half (new). ORDERED – In a number of taxa that were looked at in this study a substantial difference exists between the anteroposterior length of the dorsal and ventral portions of the lateral temporal fenestra. In many taxa, including in the outgroup taxon *Euparkeria capensis*, the ventral portion of the lateral temporal fenestra is more than twice the anteroposterior length of the dorsal portion. In all dinosaurs, except herrerasaurids and some sauropodomorphs, the difference between the anteroposterior lengths of the dorsal and ventral portions of this fenestra is much less. Indeed, in some ornithischian taxa, this difference is reversed from that which is seen in *Euparkeria* i.e. the dorsal portion is of greater anteroposterior length than the ventral portion. This character is treated as ordered to homologise the reduction in the anteroposterior length of the ventral portion of the lateral temporal fenestra relative to the dorsal portion.

**71.** Form of contact between the quadratojugal and the squamosal: 0, small, thin point contact; 1, large, quadratojugal has broad contact with the ventral margin of the descending process of the squamosal as a butt joint; 2, large, quadratojugal has broad contact with the posterior margin of the descending process of the squamosal as an elongate scarf joint (new). ORDERED – This character is treated as ordered to homologise the presence of a large contact between the quadratojugal and the descending process of the squamosal.

**117.** Foramen for trigeminal nerve and middle cerebral vein: 0, combined and undivided; 1, at least partially subdivided by prootic; 2, fully divided (modified from Gower and Sennikov, 1996; Gower, 2002; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologise the presence of a subdivision within the foramen from the trigeminal nerve and middle cerebral vein.

**145.** Retroarticular process, upturn: 0, present and strong, retroarticular forms nearly a right angle with the rest of the mandible; 1, present and subtle, retroarticular is slightly upturned at its distal end; 2, absent, retroarticular extends straight out from the caudal part of the mandible, or turns slightly downward (new). ORDERED – This character is treated as ordered to homologise the reduction in angle formed between the distal and proximal portions of the retroarticular process. In most dinosaurs, with the notable exception of herrerasaurids, the retroarticular is only slightly upturned at its distal end or is completely straight (entirely posteriorly oriented). In the outgroup taxon *Euparkeria capensis* the retroarticular is upturned at its distal end to form almost a 90 degree angle with the proximal portion of the process.

- 167.** Dentition: 0, homodont; 1, slightly heterodont, with small observable changes across tooth rows; 2, markedly heterodont, clearly distinct types of teeth present (modified from Parrish, 1993; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologise the presence of a heterodont dentition.
- 169.** Maxillary/dentary tooth, serrations: 0, absent; 1, present as small fine knifelike serrations; 2, present and enlarged and coarser (lower density) denticles. (modified from Gauthier et al., 1988; Juul, 1994; Dilkes, 1998; Irmis et al., 2007; Butler et al., 2008; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologise the presence of maxillary and dentary tooth serrations. This character was also treated as ordered by Nesbitt (2011).
- 174.** Recurvature in majority of maxillary and dentary teeth: 0, strong recurvature present; 1, weak recurvature present; 2, recurvature absent (modified from Butler et al., 2008) ORDERED – This character is treated as ordered to homologise the reduction of recurvature in the majority of maxillary and dentary teeth.
- 180.** Conical, often unserrated tooth crowns: 0, absent, 1, present together with serrated crowns, 2, encompasses all dental elements of maxilla and dentary (new). ORDERED – This character is treated as ordered to homologise the presence of conical and unserrated tooth crowns.
- 197.** Cervical vertebrae, pneumatic features (pleurocoels) in the anterior portion of the centrum: 0, absent; 1, present as fossae; 2, present as foramina (modified from Holtz, 1994; Rauhut, 2003; Smith et al., 2007; Nesbitt, 2011) ORDERED – This character is treated as ordered following Nesbitt (2011).
- 199.** Elongation of cervical centrum (cervicals 3–5): 0, less than 3.0 times the centrum height, 1, 3.0–4.0 times the centrum height, 2, >4.0 times the centrum height (Upchurch, 1998; Pol et al., 2011b) ORDERED – This character is treated as ordered following Pol et al. (2011b).
- 206.** Angle formed between pre- and postzygapophyses on anterior-to-middle cervical vertebrae: 0, very large, around 40 degrees, or over; 1, large, around 30 degrees; 2, small, around 20 degrees (new). ORDERED – This character is treated as ordered to homologise the reduction in angle between the pre- and postzygapophyses in the anterior and middle cervical vertebrae that is seen in a number of sauropodomorphs (e.g. *Lufengosaurus huenei*, ~30 degrees and *Coloradisaurus brevis*, ~20 degrees). Most dinosaurian taxa possess anterior and middle cervical vertebrae in which the pre- and postzygapophyses form an angle of around 40 degrees.
- 214.** Dorsals, number: 0, 12–14; 1, 15; 2, 16 or more (modified from Butler et al., 2008) ORDERED – This character was treated as ordered following Butler et al. (2008).
- 215.** Sacrals, number: 0, two; 1, three; 2, four/five; 3, six or more (Butler et al., 2008) ORDERED – This character was treated as ordered following Butler et al. (2008).
- 222.** Number of dorsosacral vertebrae: 0, none; 1, one; 2, two (Gauthier, 1986; Yates, 2007; Ezcurra, 2010). ORDERED – This character was treated as ordered to homologise the presence of a dorsosacral vertebrae.
- 251.** Humerus/femur ratio: 0, roughly equal to or less than 0.6; 1, greater than 0.6 but less than 0.8; 2, greater than 0.8 (modified from Gauthier, 1986). ORDERED- This character was treated as ordered to homologise the possession of a humerus that is over 60% the length of the femur.
- 269.** Proximal width of the first metacarpal respect to its length: 0, less than 65% of its length, 1, 65%–80% of its length, 2, greater than 80% of its length, 3: broader proximally than long (Serenó,

1999; Pol et al., 2011b). ORDERED – This character was treated as ordered following Pol et al. (2011b).

**272.** Manual length (measured as the average length of digits I–III): 0, accounts for less than 0.3 of the total length of humerus plus radius; 1, more than 0.3 but less than 0.4 of the total length of humerus plus radius; 2, more than 0.4 of the total length of humerus plus radius (modified from Gauthier, 1986; Langer and Benton, 2006; Nesbitt, 2011) ORDERED – This character was treated as ordered following Nesbitt (2011).

**286.** Ventrolateral twisting of the transverse axis of the distal end of the first phalanx of manual digit one relative to its proximal end: 0, absent, 1, present proximodorsal lip aligned with dorsal margin of medial distal condyle, 2, present proximodorsal lip aligned with central region of medial ligament pit of the distal condyle (Sereno, 1999; Pol et al., 2011b; Otero et al., 2015). ORDERED – This character was treated as ordered following Pol et al. (2011b).

**289.** Manual digit IV: 0, five or four phalanges; 1, three or two phalanges; 2, one phalanx; 3, phalanges absent (Gauthier, 1986; Benton and Clark, 1988; Sereno et al., 1993; Novas, 1996; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011) ORDERED – This character was treated as ordered to homologise the reduction of the number of phalanges in digit IV.

**303.** Ilium, distinct fossa present for the attachment of the *M. caudifemoralis brevis* (brevis shelf): 0, absent; 1, present as an embankment on the lateral side of the posterior portion of the ilium; 2, present, not visible in lateral view and is in the form of a fossa on the dorsal margin of the ilium and/or the ventral surface of postacetabular process (modified from Gauthier and Padian, 1985; Gauthier, 1986; Juul, 1994; Novas, 1996; Benton, 1999; Hutchinson, 2001a; Butler et al., 2008; Nesbitt, 2011). ORDERED – This character was treated as ordered to homologise the presence of a brevis fossa on the ilium. This character was also treated as ordered by Nesbitt (2011).

**305.** Ilium, ridge (or buttress) extending from the middle of the supraacetabular crest to the lateral edge of the preacetabular process: 0, absent; 1, present, low and rounded swelling; 2, present, pronounced and sharp (buttress) (new). ORDERED – This character is treated as ordered to homologise the presence of a ridge that extends from the middle of the supraacetabular crest to the lateral edge of the preacetabular process.

**307.** Length of the postacetabular process as a percentage of the total length of the ilium: 0, more than 35%; 1, 35%–25%; 2, 20% or less (Butler et al., 2008) ORDERED – This character was treated as ordered to homologise the reduction of the length of the postacetabular process following Butler et al. (2008).

**313.** Supraacetabular crest of ilium: 0, not extended along (only at the base of) the pubic peduncle; 1, extended along the pubic peduncle as a faint ridge; 2, extended along the full length of the pubic peduncle and contacts the distal end as a well-developed crest (Ezcurra, 2010). ORDERED – This character is treated as ordered to homologise the presence of a portion of the supraacetabular crest on the pubic peduncle.

**322.** Ischial shaft: 0, tapers distally; 1, expands weakly, or is parallel-sided, distally; 2, distally expanded into a distinct 'foot' or 'boot' (modified from Butler et al., 2008). ORDERED – This character is treated as ordered to homologise the presence of an expanded distal end of the ischium.

**333.** Shaft of pubis (postpubis), shape in cross-section: 0, blade-shaped; 1, rod-like; 2, rod-like, but with a tapering medial margin (tear-drop shaped) (modified from Butler et al., 2008). ORDERED –

This character is treated as ordered to homologue the two morphologies that can be described as rod-like.

**334.** Shaft of pubis (postpubis), length: 0, longer than or approximately equal in length to the ischium; 1, reduced, extends two-thirds to one-half of the length of the ischium; 2, splint-like (modified from Butler et al., 2008) ORDERED – This character is treated as ordered to homologue a reduction of the pubic shaft. This character was divided into two characters by Butler et al. (2008) but is combined into one ordered character here, to the same effect.

**338.** Openings in the body of the pubis (obturator foramen): 0, absent, no obturator process or notch; 1, one, single obturator foramen or obturator notch present; 2, two, distinct second opening in the main body (“ceratosaur” foramen) (new). ORDERED – This character is treated as ordered to homologue the presence of openings in the body of the pubis.

**353.** Femur, proximal portion, anteromedial tuber: 0, absent; 1, small and rounded; 2, offset medially (or posteriorly) relative to the posteromedial tuber (Gauthier, 1986; Benton, 1999; Clark et al., 2000; Olsen et al., 2000; Benton and Walker, 2002; Sues et al., 2003; Clark et al., 2004; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue the presence of an anteromedial tuber.

**360.** Medial bowing of the femur: 0, present, strong sigmoidal profile in anterior/posterior view; 1, present, small medial bowing forming gentle continuous curve; 2, absent, femur is straight in anterior/posterior view (new). ORDERED – In the outgroup taxon *Euparkeria capensis* and most dinosauriforms the femur is strongly sigmoidal. In some dinosaurs the medial bowing that produces the sigmoidal profile seen in other taxa is reduced. In some taxa the medial bowing is completely absent, for example in derived sauropodomorphs. This character is treated as ordered to homologue the reduction of medial bowing along the length of the femur.

**376.** Transverse groove on femur, form: 0, transverse groove is shallow, poorly developed and is straight; 1, transverse groove is deep and well developed and is straight; 2, transverse groove is deep and well developed and is curved (modified from Ezcurra, 2006; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue the presence of a deep and well developed transverse groove on the proximal portion of the femur.

**378.** Fourth trochanter of femur, shape: 0, low, mound-like and rounded; 1, raised, prominent ridge (aliform); 2, raised and pendant or rod-like (modified from Butler et al., 2008; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue the presence of a fourth trochanter on the femur.

**387.** Tibia, proximal portion, cnemial crest: 0, absent; 1, present and anteriorly straight; 2, present and curved anterolaterally (Benton and Clark, 1988; Juul, 1994; Novas, 1996; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue the presence of a cnemial crest.

**393.** Tibia, posterolateral flange (posterolateral process, descending process) of the distal portion: 0, absent; 1, present and contacts fibula; 2, present and extends well posterior to the fibula (modified from Novas, 1992; Juul, 1994; Benton, 1999; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue the presence of a posterolateral flange on the distal end of the tibia.

**442.** Metatarsal V, phalanges: 0, present and “fully” developed first phalanx; 1, present and “poorly” developed first phalanx; 2, without phalanges (modified from Gauthier, 1984; Parrish,



1993; Nesbitt, 2011). ORDERED – This character is treated as ordered to homologue reduction of digit V of the pes.

**446.** Digit 1: 0, metatarsal I robust and well-developed, distal end of phalanx 1–1 projects beyond the distal end of metatarsal II; 1, metatarsal I reduced, end of phalanx 1–1 does not extend much beyond the end of metatarsal II if at all; 2, metatarsal I reduced to a vestigial splint or absent, does not bear digits (Butler et al., 2008) ORDERED – This character is treated as ordered to homologue the reduction of digit I relative to digit II of the pes.

To test whether or not the choice of which characters are treated as ordered is having an effect on the fundamental tree topology in the main analyses of this study, an additional analysis was also carried out in which no characters were treated as ordered. This results of this analysis are shown in Extended Data Figure 4.

### 1.3 Testing the effects of taxon sampling and character weighting

In order to more rigorously test the main results of the phylogenetic analyses that are presented in this study, the potential effects of ingroup taxon sampling and character weighting were investigated through a number of additional analyses.

In the first set of additional analyses various taxa (and combinations of taxa) were excluded, particularly those that were recovered in ‘basal’ positions within the main dinosaurian clades. This was done in order to test whether or not the fundamental shape of the trees that are produced by our additional, reduced analyses would differ from those recovered in the most inclusive analyses. Taxa that have previously proved problematic in terms of their position within Dinosauria, such as *Eoraptor lunensis* and *Agnosphitys cromhallensis* were excluded in some additional analyses, as were fragmentary taxa, such as *Pisanosaurus mertii* and *Saltopus elginensis*. Additionally, ‘clusters’ of taxa from each group were systematically removed from the data matrix and additional analyses were run with these reduced taxon samples as well (for example, an analysis was run in which *Eoraptor lunensis*, *Tawa hallae* and *Eodromaeus murphy*, three taxa traditionally recovered near the stem of the theropod lineage, were all removed from the dataset). The recovery of Ornithoscelida as a monophyletic clade, as well as Sauropodomorpha+Herrerasauridae (Saurischia, new definition), occurred in all of these analyses, regardless of which taxa were included or excluded. These results demonstrate the stability of the topology recovered by the analyses of this study and suggests that minor differences in taxon sampling have no effect on tree topology.

While the primary analyses of this study used equal weighting for the anatomical characters, additional analyses were also run using the implied weighting method. In each of these, a different weighting score was entered into TNT 1.5-beta (i.e. piwe = 3, 5, 10) and strict consensus trees were produced for each. With both implied weighting and equal weighting, the same fundamental tree topology is recovered, including the recovery of a monophyletic Ornithoscelida.

### 1.4 The phylogenetic position of *Saltopus elginensis*

*Saltopus elginensis* is recovered, in the strict consensus, in a polytomy with Dinosauria and Silesauridae. These taxa are united by a number of characters (see below). The lack of clear resolution in this part of the tree results, in part, from the incomplete nature and poor preservation

of the only known specimen of *Saltopus* (only elements of the post-cervical axial column, pelvic and pectoral girdles and fragmentary fore- and hind limbs are preserved as natural moulds, on part and counterpart slabs).

In a 50% majority rule consensus tree, *Saltopus elginensis* is recovered as the sister taxon to Dinosauria. This position is supported by three characters – a humerus with a proximal articular surface that is not continuous with the deltopectoral crest, a radius that is shorter than 80% of the humerus length and an ischium with a large, non-articulating surface between its pubic and iliac articular processes. However, given the nature of the type material, some of these character states are hard to assess, and so the interpretations of Benton and Walker (2011) were followed herein. Having a Northern Hemisphere taxon positioned so close to the base of Dinosauria hints at a possible non-Gondwanan origin for Dinosauria. This basal, Carnian dinosauriform, while fragmentary, and its positions within our new framework, provides much scope for future studies and discussion.

### 1.5 *Eoraptor lunensis*: A member of Theropoda or Sauropodomorpha?

*Eoraptor* is an important early dinosaur. At the time of its discovery it was believed to represent a basal theropod (Serenó et al. 1993), but subsequent studies recovered it in a number of different positions within the dinosaur tree, the most controversial of which is the recovery of *Eoraptor* as one of the basal-most sauropodomorphs (Martínez et al. 2011; Sereno et al. 2013). This position was based upon a number of supposed sauropodomorph features in the holotype and referred material. Our analysis, as well as a number of other recent studies (Ezcurra 2010; Nesbitt 2011), finds *Eoraptor* to be a basal member of Theropoda.

MGB's first-hand examination of the material referred to *Eoraptor* found that several of the key features reported as present in *Eoraptor*, and used to unite it with members of Sauropodomorpha, were absent, missing or ambiguous. For example, some features, such as the described presence of a subnarial foramen between the premaxilla and maxilla, represent misinterpretation of the anatomy and the effects of fossilisation on the material (Serenó et al. 2013). Furthermore, the referral of PVSJ 559 to *Eoraptor* is considered here to be dubious - the referral is not based upon the presence of apomorphies but is instead reliant on an assumption that there was only one small-bodied sauropodomorph in the Ishigualasto Formation. Thus, characters that are cited as being present or absent in *Eoraptor* based upon this referred material should be considered with caution.

The few 'sauropodomorph-like' features that do appear in *Eoraptor* are inferred to be dinosaur symplesiomorphies that were retained as a result of its extremely basal position within Ornithoscelida. As the earliest known member of Ornithoscelida, *Eoraptor* may serve as a good model for the ancestral condition for this group, and also, with the number of plesiomorphic conditions shared with basal members of Saurischia (new definition), it may also give us good insights into the ancestral conditions for Dinosauria.

### 1.6 *Agnosphytis cromhallensis* as a member of Silesauridae

The enigmatic British taxon, *Agnosphytis cromhallensis*, is recovered here as a member of Silesauridae. However, the spread of characters within the material belonging to this taxon is complex. Some elements of this material would, on their own, suggest a different position within the tree: for example, the 'more derived' nature of elements like the astragalus suggest a dinosaurian

affinity for *Agnosphytis* (Fraser et al. 2002). It is possible that the material belonging to *Agnosphytis* could represent a chimaera as it is based on disarticulated fissure fill material. The maxilla (VMNH 1751) seems almost certainly of silesaurid affinity, due to the ankylosed nature of its teeth. Other elements such as the humerus (VMNH 1750) also appear very similar to those same elements in other silesaurid taxa. The holotype specimen (VMNH 1745), a left ilium, appears much more similar to those of basal sauropodomorphs such as *Saturnalia tupiniquim* and *Guaibasaurus candelariensis*. However, further work is needed on this taxon to better establish its position within Dinosauromorpha.

### 1.7 Position and significance of *Nyasasaurus parringtoni*

Our initial analysis included *Nyasasaurus parringtoni*, as it represents an early, and possibly very important, dinosauriform (Nesbitt et al. 2013). In our analyses (74 taxa in total) we consistently recovered *Nyasasaurus* as a derived member of Sauropodomorpha, most closely related to taxa like *Massospondylus* and *Coloradisaurus* (Extended Data Figure 5). This result was also recovered in some of the analyses of Nesbitt et al. (2013: though not in their preferred tree) and, if true, has numerous implications for the timing of origins for Dinosauria, Saurischia and Sauropodomorpha.

When *Nyasasaurus parringtoni* was named it was suggested to represent either the earliest known dinosaur or the closest outgroup to Dinosauria (Nesbitt et al. 2013). Indeed, its early appearance in the fossil record (Anisian) hints at a possible basal position for *Nyasasaurus parringtoni* within the dinosaurian lineage. For these reasons, it is surprising that *Nyasasaurus* was recovered so well-nested within Sauropodomorpha. However, consideration of its anatomy, especially comparison with Early Jurassic forms like *Massospondylus*, show clearly how, at least some elements within the hypodigm of *Nyasasaurus*, could represent a massospondylid sauropodomorph. While a monophyletic Massospondylidae was not recovered by our analysis, the polytomy of sauropodomorphs more derived than Plateosauridae does contain a number of taxa traditionally considered to be massospondylids, and it is within this grade of taxa that we recover *Nyasasaurus*.

If the age of the section of the Manda beds that *Nyasasaurus* was recovered from is correct (Anisian), then the inferred divergence times of all major clades within Dinosauria would move considerably further back in time (compare Figure 1 to Extended Data Figure 5). However, the age of the Manda beds is currently under review (S. J. Nesbitt, pers. comm.) and so the dates for the origins of Dinosauria (and its major lineages) that we have inferred from it may also be subject to change. Presently, we do not include *Nyasasaurus* in our discussion of dinosaur origins, in order to negate the effects that this poorly-dated taxon has on our interpretations.

The time-calibrated strict consensus tree that contained *Nyasasaurus parringtoni* was created using the R-package: strap (Bell and Lloyd 2015), with ages for taxa taken from the relevant literature.

### 1.8 Origins of Dinosauria and the major dinosaurian lineages

With the exclusion of *Nyasasaurus parringtoni* from our analyses, a model of early dinosaur evolution that is much more congruent with the fossil record is recovered. The major radiations within Dinosauria (when not skewed by the Anisian age of *Nyasasaurus*) are found to fall within the Middle Triassic. The origin of Dinosauria is placed here on the Olenekian-Anisian boundary. Both this date and those dates predicted for the radiations of the major dinosaurian lineages are earlier than has been previously proposed (Brusatte et al. 2010; Ezcurra 2010; Nesbitt 2011). Fossil trackways

from the early Olenekian have hinted at the possible presence of dinosaurs (or close dinosaur relatives) during this part of the Middle Triassic (Brusatte et al. 2011) and our new model may help to explain these occurrences.

### 1.9 Origins of feathers?

The question of when feathers/feather-like structures originated in dinosaurs, and possibly their ancestors, may also find a new solution within our new evolutionary hypothesis. The discovery of a complex integumentary covering in the ornithischian *Kulindadromeus* (Godefroit et al. 2014), as well as the presence of other branched integumentary structures in the heterodontosaurid *Tianyulong* (Zheng et al. 2009), has opened a debate on whether or not all dinosaurs may have been covered, at least in part, by these kinds of structures, including members of Sauropodomorpha. In this new hypothesis, should the feather-like integument seen in some members of Ornithischia and Theropoda actually be homologous, the origin of these features may then coincide with the origin of Ornithoscelida; there would be no evidence for, or reason to assume, the presence of such features in sauropodomorphs, saurischians, or any groups more basal to them, as has been discussed in previous hypotheses, nor would they be primitive for Dinosauria as a whole (see Barrett et al. 2015).

### 1.10 Defining the major dinosaur groups

Our research necessitates several changes to currently used definitions of a number of major dinosaurian lineages in order to preserve the stability of traditionally groups. Here, we factor in elements of our new phylogenetic hypothesis (and make allowance for any subsequent revisions it may undergo) and propose the following clade definitions herein:

**Table S2:** Current and new definitions for the major dinosaurian clades.

Clade	Current definition	New definition
<b>Dinosauria</b>	The least inclusive clade containing <i>Triceratops horridus</i> and <i>Passer domesticus</i> (Sereno 2005)	The least inclusive clade that includes <i>Passer domesticus</i> , <i>Triceratops horridus</i> and <i>Diplodocus carnegii</i>
<b>Ornithoscelida</b>	[Megalosauridæ, Scelidosauridæ, and Iguanodontidæ] and the Compsognatha (Huxley 1870)	The least inclusive clade that includes <i>Passer domesticus</i> and <i>Triceratops horridus</i>
<b>Saurischia</b>	The most inclusive clade containing <i>Passer domesticus</i> and <i>Saltasaurus loricatus</i> but not <i>Triceratops horridus</i> (Sereno 2005)	The most inclusive clade that contains <i>Diplodocus carnegii</i> but not <i>Triceratops horridus</i>
<b>Theropoda</b>	The most inclusive clade containing <i>Passer domesticus</i> but not <i>Saltasaurus loricatus</i> (Sereno 2005)	The most inclusive clade that contains <i>Passer domesticus</i> but not <i>Diplodocus carnegii</i> or <i>Triceratops horridus</i>

<b>Ornithischia</b>	The most inclusive clade containing <i>Triceratops horridus</i> but not <i>Passer domesticus</i> or <i>Saltasaurus loricatus</i> (Sereno 2005)	The most inclusive clade that contains <i>Triceratops horridus</i> but not <i>Passer domesticus</i> or <i>Diplodocus carnegii</i>
<b>Sauropodomorpha</b>	The most inclusive clade including <i>Saltasaurus</i> but not <i>Tyrannosaurus rex</i> (McPhee et al. 2014; sensu Taylor et al. 2010)	The most inclusive clade that contains <i>Diplodocus carnegii</i> but not <i>Triceratops horridus</i> , <i>Passer domesticus</i> or <i>Herrerasaurus ischigualastensis</i>
<b>Herrerasauridae</b>	The least inclusive clade that includes <i>Herrerasaurus ischigualastensis</i> and <i>Staurikosaurus pricei</i> (Novas 1992)	The least inclusive clade that includes <i>Herrerasaurus ischigualastensis</i> and <i>Staurikosaurus pricei</i> (Novas 1992)

If our results are not supported by future studies, and a traditional Saurischia is recovered, the clade defined by *Passer* + *Triceratops* would then include the same taxa as *Passer* + *Triceratops* + *Diplodocus*, thus, Ornithoscelida would become redundant, as it is junior to Dinosauria. In this way, the scheme that we propose has the ability to self-correct should future studies refute our hypothesis. Our definition of Saurischia would also allow a very simple transition back into a more traditional hypothesis, as it does not depend on the phylogenetic placement of Theropoda.

Our new definition of Theropoda is designed to keep the clade both stable and valid, even as the fundamental shape of the dinosaurian tree fluctuates between differing hypotheses and as the positions of a few key, early taxa become subject to changes as well.

We also redefine Sauropodomorpha, as the current definition (Taylor et al. 2010; McPhee et al. 2014) would, within our new framework, force the inclusion of the problematic group Herrerasauridae, and therefore encompass the same animals as the newly redefined Saurischia. As Saurischia is older, it could make Sauropodomorpha redundant. To avoid this, and any further confusion, we propose redefining the group Sauropodomorpha to specifically exclude Herrerasauridae. However, we intentionally do not exclude Herrerasauridae in the definition of Theropoda, as we understand that future studies may recover a 'true theropod'+Herrerasauridae relationship, in which Herrerasauridae falls closer to traditional theropods than to Sauropodomorpha and Ornithischia, as it has done in some previous analyses (Nesbitt et al. 2009b; Nesbitt 2011). In such a case, Herrerasauridae would be regarded as being within Theropoda, without the need for any further changes to definitions.

The name Eusaurischia becomes redundant, as it encompasses the same group of animals as Dinosauria (new definition); Dinosauria takes priority as it is the older of the two names.

## 2.0 Previous work: A brief discussion

A large number of previous studies have attempted to address the question of dinosaur interrelationships (e.g. Gauthier 1986; Novas 1996; Sereno 1999; Yates 2003; Benton 2004; Langer and Benton 2006; Ezcurra 2006; Yates 2007; Ezcurra 2010; Langer et al. 2010; Nesbitt 2011). Studies have ranged in size, in terms of both the number of taxa that they contain and the number of characters. Additionally, the range of sampled taxa and characters has varied, with some studies

focusing more on one particular dinosaurian group over others (Yates 2003; Ezcurra 2006; Yates 2007). In all of these studies, the original division of Dinosauria into two groups, Ornithischia and Saurischia, as originally proposed by Seeley (1887, 1888), was recovered. Ornithischia is consistently recovered as a monophyletic group in those studies that include multiple ornithischian taxa (Ezcurra 2006; Nesbitt 2011). However, many studies fail to include a range of ornithischian taxa, instead scoring the clade as a single supra-specific operational taxonomic unit (OTU) (e.g. Yates 2003; Langer and Benton 2006; Ezcurra 2010). This is problematic, as there are a number of features that are present in ornithischian taxa, particularly basal forms such as *Heterodontosaurus* and *Eocursor*, that are often only regarded as being present in certain saurischians, as has been demonstrated by Butler et al. (2007, 2008) and noted by other authors such as Nesbitt (2011), Padian (2013) and Galton (2014).

The saurischian part of the dinosaur clade has been more unstable than the ornithischian clade, with numerous hypotheses having been proposed for the arrangement of taxa within it, with the main issue of contention being the phylogenetic position of herrerasaurids and *Eoraptor* (Nesbitt et al. 2009b; Ezcurra 2010; Nesbitt 2011; Novas et al. 2011; Sereno et al. 2012). Padian et al. (1999) erected Eusaurischia to contain all but the basal most members of Saurischia, however, Nesbitt (2011) found this clade to be synonymous with Saurischia, with *Eoraptor*, *Herrerasaurus* and *Staurikosaurus* being recovered as theropods.

The monophyly of Sauropodomorpha has been widely accepted (Langer and Benton 2006; Ezcurra 2006, 2010), and most major recent studies that include a wide range of early, basal sauropodomorphs tend to be focused upon resolving the interrelationships further up the tree (Yates 2003, 2007; Pol et al. 2011; McPhee et al. 2014). With the exception of the positions of a few basal saurischian taxa, the nature of the close phylogenetic relationship between sauropodomorphs and theropods has been consistently recovered (Langer and Benton 2006; Ezcurra 2006, 2010; Nesbitt 2011).

### 3.1 Institutional abbreviations

**AMNH**, American Museum of Natural History, New York, USA; **BP**, Evolutionary Studies Institute (formerly Bernard Price Institute for Palaeontological Research), Johannesburg, South Africa; **BRSMG**, Bristol City Museums and Art Gallery, Bristol, UK; **CM**, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA; **FMNH**, Field Museum of Natural History, Chicago, USA; **IVPP**, Institute of Vertebrate Paleontology and Paleoanthropology, Beijing, China; **MBLUZ**, Museo de Biología de la Universidad del Zulia, Maracaibo, Venezuela; **MCZ**, The Louis Agassiz Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA; **NGMJ**, Nanjing Geological Museum, Nanjing, China; **NHMUK**, The Natural History Museum, London, UK; **PVL**, Instituto Miguel Lillo, Tucumán, Argentina; **PVSJ**, Museo de Ciencias Naturales, San Juan, Argentina; **SAM**, Iziko South African Museum, Cape Town, South Africa; **USFM**, Federal University of Santa Maria, Santa Maria, Brazil; **USNM/NMNH**, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA; **VMNH**, Virginia Museum of Natural History, Martinsville, Virginia, USA; **ZDM**, Zigong Dinosaur Museum, Zigong, Sichuan, China; **ZPAL**, Institute of Paleobiology of the Polish Academy of Sciences in Warsaw, Poland.

**Table S3.** Taxon list and sources. Specimen numbers indicate direct observation by at least one author (bold text). Other sources of character data are taken from the literature cited.

**Taxon**

*Aardonyx celestae*  
*Abriotosaurus consors*  
*Agilisaurus louderbacki*  
*Agnosphitys cromhallensis*  
*Antetonitrus ingenipes*  
*Asilisaurus kongwe*  
*Chindesaurus bryansmalli*  
*Coelophysis bauri*  
*Coloradisaurus brevis*  
*Cryolophosaurus ellioti*  
*Dilophosaurus wetherilli*  
*Diodorus scytobrachion*  
*Dracoraptor hanigani*  
*Dracovenator regenti*  
*Dromomeron gigas*  
*Dromomeron gregorii*  
*Dromomeron romerii*  
*Efraasia minor*  
*Emausaurus ernsti*  
*Eocursor parvus*  
*Eodromaeus murphi*  
*Eoraptor lunensis*  
*Eucoelophysis baldwini*  
*Euparkeria capensis*  
*Fruitadens haagarorum*  
*Gongxianosaurus shibeiensis*  
*Guaibasaurus candelariensis*  
*Herrerasaurus ischigualastensis*  
*Heterodontosaurus tucki*  
*Hexinlusaurus multidens*  
*Ignotosaurus fragilis*  
*Jeholosaurus shangyuanensis*  
*Lagerpeton chanarensis*  
*Laquintasaura venezuelae*  
*Lesothosaurus diagnosticus*  
*Lewisuchus/Pseudolagosuchus*  
*Leyesaurus marayensis*  
*Liliensternus liliensterni*  
*Lophostropheus airelensis*  
*Lufengosaurus huenei*  
*Lutungutali sitwensis*  
*Manidens condorensis*  
*Marasuchus lilloensis*  
*Massospondylus carinatus*  
*Massospondylus kaalea*

**Source(s)**

Yates et al. 2010  
**NHMUK PV RU B52**; Sereno 2012  
**ZDM 6011**; Peng 1992; Barrett et al. 2005a  
Fraser et al. 2002  
McPhee et al. 2014  
Nesbitt et al. 2010  
Nesbitt et al. 2007  
**AMNH 7223, 7224, 7239, 30576, 30614, 30615, 30631; CM 81765, 82932**  
**PVL 3967, 5904**; Apaldetti et al. 2013, 2014  
Smith et al. 2007  
Rowe and Gauthier 1990  
Kammerer et al. 2012  
Martill et al. 2016  
**BP/1/5243**; Yates 2005  
Martinez et al. 2015  
Nesbitt et al. 2009a  
Irmis et al. 2007  
Galton 1973; Yates 2003  
Haubold 1990  
**SAM-PK-K8025**; Butler 2010  
**PVSJ 560-562**; Martinez et al. 2011  
**PVSJ 512**; Sereno et al. 2013  
Sullivan and Lucas 1999; Nesbitt et al. 2007  
Ewer 1965; Gower and Weber 1998  
Butler et al. 2012  
He et al. 1998  
Bonaparte et al. 1999  
**PVL 2566; PVSJ 407**; Novas 1994; Sereno 1994; Sereno and Novas 1994  
**SAM-PK-K337, K1332**; Norman et al. 2011; Sereno 2012; Galton 2014  
**ZDM 6001-2**; Barrett et al. 2005a  
Martinez et al. 2012  
**Multiple specimens – IVPP**; Barrett and Han 2009; Han et al. 2012  
**PVL 4619, PVL 4625**; Sereno and Arcucci 1994a  
**Multiple specimens – MBLUZ**; Barrett et al. 2014  
**Multiple specimens – NHMUK, SAM-PK**; Porro et al. 2015; Baron et al. 2016  
Bittencourt et al. 2015  
**PVSJ 706**; Apaldetti et al. 2011  
Rowe and Gauthier 1990  
Ezcurra and Cuny 2007  
**IVPP V15**; Young 1941; Barrett et al. 2005b  
Peacock et al. 2013  
Pol et al. 2011a  
**PVL 870-871**; Sereno and Arcucci 1994b  
**Multiple specimens - BP, NHMUK**; Gow 1990; Barrett and Yates 2005  
**SAM-PK-K1325**; Barrett 2009

<i>Nyasaosaurus parringtoni</i>	<b>NHMUK PV R6856</b> ; Nesbitt et al. 2013
<i>Pampadromaeus barberenai</i>	Cabreira et al. 2011
<i>Panguraptor lufengensis</i>	You et al. 2014
<i>Panphagia protos</i>	<b>PVSJ 874</b> ; Martinez and Alcober 2009; Martinez et al. 2012
<i>Pantydraco caducus</i>	<b>NHMUK PV P24</b> ; Yates 2003
<i>Pisanosaurus mertii</i>	<b>PVL 2577</b> ; Bonaparte 1976
<i>Plateosaurus engelhardti</i>	Yates 2003; Galton and Upchurch 2004
<i>Postosuchus kirkpatricki</i>	Chatterjee 1985
<i>Procompsognathus triassicus</i>	<b>SMNS 12591</b> ; Sereno and Wild 1992
<i>Pulanesaura eocollum</i>	McPhee et al. 2015
<i>Riojasaurus incertus</i>	<b>PVL 3808</b>
<i>Sacisaurus agudoensis</i>	Ferigolo and Langer 2007
<i>Saltopus elginensis</i>	Benton and Walker 2011
<i>Sanjuansaurus gordilloi</i>	<b>PVSJ 605</b> ; Alcober and Martinez 2010
<i>Sarcosaurus woodi</i>	<b>NHMUK PV 4840/1</b>
<i>Saturnalia tupiniquim</i>	Langer 2003; Langer and Benton 2006; Langer et al. 2007
<i>Scelidosaurus harrisonii</i>	<b>NHMUK PV R1111, R6704; BRSMG CE12785</b> ; Norman et al. 2004
<i>Silesaurus opolensis</i>	<b>ZPAL Ab III/361</b> ; Dzik 2003
<i>Sinosaurus triassicus</i>	Shaojin 1993; Xing et al. 2014
<i>Staurikosaurus pricei</i>	Galton 1977
<i>Syntarsus kayentakatae</i>	<b>MCZ 9175; USNM 442404</b> ; Rowe 1989
<i>Tawa hallae</i>	<b>AMNH 30881, 30886</b> ; Nesbitt et al. 2009b
<i>Tazoudasaurus naimi</i>	Allain et al. 2004
<i>Thecodontosaurus antiquus</i>	Benton et al. 2000
<i>Tianyulong confuciusi</i>	Zheng et al. 2009; Sereno 2012
<i>Unaysaurus toletinoi</i>	<b>UFSM 11069</b> ; Leal et al. 2004
<i>Vulcanodon karibaensis</i>	Cooper 1984
<i>Yunnanosaurus huangi</i>	<b>NGMJ 004546</b> ; Young 1942
<i>Zupaysaurus rougieri</i>	Rowe and Gauthier 1990; Ezcurra 2007; Ezcurra and Novas 2007

### 3.2 Character list

1. Skull proportions: 0, preorbital skull length more than 45% of basal skull length; 1, preorbital length less than 45% of basal skull length (modified from Butler et al., 2008).
2. Skull length (rostral–quadrate): 0, 15% or less of body length; 1, 20–30% of body length (modified from Butler et al., 2008).
3. Skull length: 0, longer than two thirds of the femoral length; 1, shorter than two-thirds of the femoral length (Gauthier, 1986; Ezcurra, 2010; Nesbitt, 2011).



4. Skull shape: 0, with a deep snout (depth of skull just anterior to the orbit is subequal to depth of the rostral portion of the skull); 1, tapered rostrally (depth of skull just anterior to the orbit is far greater than the depth of the rostral portion of the skull). NEW
5. Profile of premaxilla: 0, convex; 1, with an inflection at the base of the anterodorsal process (Upchurch, 1995; Ezcurra, 2010).
6. Premaxilla, edentulous anterior region: 0, absent, first premaxillary tooth is positioned adjacent to the symphysis; 1, present, first premaxillary tooth is inset the width of one or more crowns (Butler et al., 2008).
7. Premaxilla, posterodorsal process (maxillary process, posterolateral process, subnarial process), length: 0, does not contact lacrimal; 1, contacts the lacrimal, excludes maxilla–nasal contact (Butler et al., 2008)
8. Premaxilla, posterodorsal process (maxillary process, posterolateral process, subnarial process), width: 0, wide, plate-like; 1, thin, bar like (modified from Gauthier, 1986; Rauhut, 2003; Langer and Benton, 2006; Smith et al., 2007; Nesbitt, 2011).
9. Premaxilla, posterodorsal process (maxillary process, posterolateral process, subnarial process): 0, extends posteriorly to form part of the posterior margin of the external naris; 1, restricted to the ventral border of the external naris (Langer and Benton, 2006; Nesbitt, 2011).
10. Premaxilla, posterodorsal process (maxillary process, posterolateral process, subnarial process), relationship with anteroventral process of the nasal: 0, broad sutured contact; 1, point contact; 2, no contact (modified from Gauthier, 1986; Yates, 2007; Ezcurra 2010).
11. Position of the ventral (oral) margin of the premaxilla: 0, roughly level with the maxillary tooth row; 1, deflected ventral to maxillary tooth row; 2, raised, positioned dorsal to the maxillary tooth row (modified from Butler et al., 2008).
12. Premaxillary foramen (anterior premaxillary foramen): 0, absent; 1, present (Yates, 2007; Butler et al., 2008; Ezcurra, 2010).
13. Second anterior premaxillary foramen (often connected to the premaxillary foramen by a distinct anteroventrally oriented groove): 0, absent; 1, present. NEW

14. Premaxillary palate: 0, strongly arched, forming a deep, concave palate; 1, horizontal or only gently arched (Butler et al., 2008).
15. Fossa-like depression positioned on the premaxilla-maxilla boundary: 0, absent; 1, present (Butler et al., 2008).
16. Premaxilla–maxilla diastema: 0, absent, maxillary teeth continue to anterior end of maxilla; 1, present, substantial diastema of at least one crown’s length between maxillary and premaxillary teeth (Butler et al., 2008).
17. Form of diastema; 0, flat; 1, arched ‘subnarial gap’ between the premaxilla and maxilla (Butler et al., 2008).
18. Premaxilla, narial fossa: 0, absent; 1, present (modified from Sereno, 1999; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
19. Narial fossa surrounding external nares on lateral surface of premaxilla, position of ventral margin of fossa relative to the ventral margin of the premaxilla: 0, closely approaches the ventral margin of the premaxilla; 1, separated by a broad flat margin from the ventral margin of the premaxilla (Butler et al., 2008).
20. External nares, position of the ventral margin: 0, below or level with the ventral margin of the orbits; 1, above the ventral margin of the orbits (modified from Butler et al., 2008).
21. External naris, size: 0, entirely overlies the premaxilla; 1, extends posteriorly to overlie the maxilla (modified from Butler et al., 2008).
22. External naris, shape (in adults): 0, rounded or elliptical; 1, subtriangular, with an acute posteroventral corner (Galton and Upchurch, 2004; Ezcurra, 2010).
23. Level of the anterior margin of the external naris: 0, anterior to the midlength of the premaxillary body; 1, posterior to the midlength of the premaxillary body (Rauhut, 2003; Ezcurra, 2010).
24. Level of the posterior margin of the external naris: 0, anterior to or level with the premaxilla-maxilla suture; 1, posterior to the first maxillary alveolus; 2, posterior to the midlength of the

maxillary tooth row and the anterior margin of the antorbital fenestra (Wilson and Sereno, 1998; Yates, 2007; Ezcurra, 2010). ORDERED

25. Anterior premaxillary foramen, position: 0, positioned outside of the narial fossa; 1, positioned on the rim of, or inside, the narial fossa (modified from Sereno et al., 1993; Yates, 2007; Ezcurra, 2010).
26. Subnarial foramen between the premaxilla and maxilla: 0, absent; 1, present (modified from Benton and Clark, 1988; Parrish, 1993; Juul, 1994; Benton, 1999; Nesbitt, 2011).
27. Deep elliptic fossa present along sutural line of the nasals: 0, absent; 1, present; 2, fenestra (internasal fenestra) present (modified from Butler et al., 2008).
28. Internal antorbital fenestra size: 0, large, generally at least 15% of the skull length; 1, very much reduced, less than 10% of skull length, or absent (Butler et al., 2008).
29. External antorbital fenestra: 0, present; 1, absent (Butler et al., 2008).
30. Antorbital fenestra, shape: 0, triangular; 1, oval or circular; 2, rectangular (modified from Butler et al., 2008).
31. Additional opening(s) or fossa anteriorly within the antorbital fossa (promaxillary foramen, promaxillary fossa): 0, absent; 1, present (modified from Carpenter, 1992; Rauhut, 2003; Smith et al., 2007; Butler et al., 2008; Nesbitt, 2011).
32. Additional opening(s) in the antorbital fenestra (promaxillary foramen), shape: 0, wide and circular; 1, narrow recess or slit-like. NEW
33. Maxilla, rostralateral surface between the ventral border of the antorbital fossa and the alveolar margin is pierced by a small foramen: 0, absent; 1, present. NEW
34. Anterior profile of the maxilla: 0, slopes continuously towards the anterior tip; 1, with a strong inflection (notch) at the base of the ascending ramus, creating an anterior ramus with parallel dorsal and ventral margins (Sereno et al., 1996; Langer and Benton, 2006; Ezcurra, 2010; Nesbitt, 2011).

35. Maxilla, lateral surface: 0, completely smooth; 1, sharp longitudinal ridge present; 2, rounded/bulbous longitudinal ridge present (Gower, 1999; Weinbaum and Hungerbühler, 2007; Nesbitt, 2011). ORDERED
36. Maxilla, buccal emargination: 0, absent; 1, present (Butler, 2005; Irmis et al., 2007; Irmis et al., 2007; Butler et al 2008; Nesbitt, 2011).
37. Ridge or lateral swelling of lateral surface of the dentary (possibly associated with a fleshy cheek in life): 0, absent, 1, present (Gauthier, 1986; Galton and Upchurch, 2004; Pol et al., 2011b).
38. Slot in maxilla for lacrimal: 0, absent; 1, present (Butler et al., 2008).
39. Antorbital fossa: 0, restricted to the lacrimal; 1, restricted to the lacrimal and dorsal process of the maxilla; 2, present on the lacrimal, dorsal process of the maxilla and the dorsal margin of the posterior process of the maxilla (the ventral border of the antorbital fenestra) (Nesbitt et al., 2009c; Nesbitt, 2011) ORDERED
40. Dorsoventral extension of lacrimal antorbital fossa: 0, through more than half of the bone height; 1, is restricted to the ventral half of the bone (Langer, 2004; Pol et al., 2011b).
41. Nasal: 0, does not possess a posterolateral process that envelops part of the anterior (rostral) ramus of the lacrimal; 1, possesses a posterolateral process that envelops part of the anterior ramus of the lacrimal (Yates, 2003; Langer and Benton, 2006; Nesbitt, 2011).
42. Nasal: 0, does not form part of the dorsal border of the antorbital fossa; 1, forms part of the dorsal border of the antorbital fossa (modified from Sereno et al., 1994; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
43. Ventral rim of the antorbital fossa: 0, parallel to tooth row, 1, ventrally sloped in its caudal part (Langer, 2004; Pol et al., 2011b).
44. Lacrimal, shape: 0, dorsoventrally short and block-shaped; 1, dorsoventrally elongate and shaped like and inverted L (Rauhut, 2003; Ezcurra, 2010).
45. Descending process of lacrimal: 0, curved, subvertically oriented (at its dorsal half), 1, straight and obliquely oriented along its entire length (Pol et al., 2011b).

46. Length of the anterior (rostral) ramus of the lacrimal: 0, greater than half the length of the ventral ramus, 1, less than half the length of the ventral ramus (Yates, 2007; Pol et al., 2011b).
47. Lacrimal: 0, does not fold over (overhang) the posterior/posterodorsal part of the antorbital fenestra; 1, folds over (overhangs) the posterior/posterodorsal part of the antorbital fenestra (modified from Sereno, 1999; Langer and Benton, 2006; Nesbitt, 2011).
48. Dorsal crest(s) on the skull, formed by dorsoventral expansion of the lacrimals and/or nasals (naso-lacrimal crest): 0, absent; 1, present. NEW
49. Accessory ossification(s) in the orbit (palpebral/ supraorbital): 0, absent; 1, present (Butler et al., 2008).
50. Palpebral/supraorbital: 0, free, projects into orbit from contact with lacrimal/prefrontal; 1, incorporated into orbital margin (Butler et al., 2008).
51. Palpebral, shape in dorsal view: 0, rod-shaped; 1, plate-like with wide base (Butler et al., 2008).
52. Palpebral/supraorbital, number: 0, one; 1, two; 2, three (Butler et al., 2008).
53. Free palpebral, length, relative to anteroposterior width of orbit: 0, does not traverse entire width of orbit; 1, traverses entire width of orbit (Butler et al., 2008).
54. Exclusion of the jugal from the posteroventral margin of the external antorbital fenestra by lacrimal–maxilla contact: 0, absent; 1, present (Clark et al., 2000; Olsen et al., 2000; Benton and Walker, 2002; Sues et al., 2003; Clark et al., 2004; Rauhut, 2003; Langer and Benton, 2006; Butler et al., 2008; Nesbitt, 2011).
55. Anterior ramus of jugal, proportions: 0, deeper than wide; 1, wider than deep (modified from Butler et al., 2008).
56. Anterior ramus of jugal: 0, not as deep as the posterior ramus of the jugal; 1, deeper than the posterior ramus of the jugal (modified from Butler et al., 2008).

57. Position of maximum widening of the skull: 0, beneath the jugal–postorbital bar; 1, posteriorly, beneath the infratemporal fenestra (Butler et al., 2008).
58. Jugal (or jugal–epijugal) ridge dividing the lateral surface of the jugal into two planes: 0, absent; 1, present and sharp; 2, present and rounded; 3, restricted to a bulbous ridge (modified from Butler et al., 2008; Nesbitt, 2011).
59. Epijugal: 0, absent; 1, present (Butler et al., 2008).
60. Ornamentation on jugal: 0, absent; 1, present as small rugose surface; 2, present as well developed jugal boss (modified from Butler et al., 2008). ORDERED
61. Jugal, anterior extent of the slot for the quadratojugal: 0, well posterior of the posterior edge of the dorsal process of the jugal; 1, at or anterior to the posterior edge of the dorsal process of the jugal (Nesbitt, 2011).
62. Jugal, posterior process: 0, lies dorsal to the anterior process of the quadratojugal; 1, lies ventral to the anterior process of the quadratojugal; 2, is level with the anterior process of the quadratojugal and overlaps it/splits the anterior process of the quadratojugal; 3, is level with the anterior process of the the quadratojugal and is split by the anterior process of the quadratojugal (forked, bifurcated) (modified from Butler et al., 2008; Nesbitt, 2011).
63. Jugal–postorbital bar, width broader than infratemporal fenestra: 0, absent; 1, present (Butler et al., 2008).
64. Jugal–postorbital joint: 0, elongate scarf joint; 1, short butt joint (Butler et al., 2008).
65. Jugal, posterior ramus: 0, forms anterior and/or ventral margin of infratemporal fenestra; 1, forms part of posterior margin, expands towards squamosal (Butler et al., 2008).
66. Jugal-lacrimal relationship: 0, lacrimal overlapping lateral surface of jugal or abutting it dorsally; 1, jugal overlapping lacrimal laterally (Serenio et al., 1993; Ezcurra, 2010).
67. Ratio of minimum depth of jugal below the orbit to the distance between the anterior end of the jugal and the anteroventral corner of the infratemporal fenestra: 0, less than 0.2; 1, roughly equal to or greater than 0.2 (modified from Galton, 1985; Yates, 2007; Ezcurra 2010).

68. Lateral temporal fenestra, maximum anteroposterior length of ventral half: 0, more than twice the maximum anteroposterior length of the dorsal half; 1, less than twice the maximum anteroposterior length of the dorsal half; 2, maximum anteroposterior length of the dorsal half is greater than that of the ventral half. NEW, ORDERED

69. Postorbital, orbital margin: 0, relatively smooth curve; 1, prominent and distinct projection into orbit (orbital flange) (Butler et al., 2008).

70. Contact between dorsal process of quadratojugal and descending process of the squamosal: 0, present; 1, absent (Butler et al., 2008).

71. Form of contact between the quadratojugal and the squamosal: 0, small, thin point contact; 1, large, quadratojugal has broad contact with the ventral margin of the descending process of the squamosal as a butt joint; 2, large, quadratojugal has broad contact with the posterior margin of the descending process of the squamosal as an elongate scarf joint. NEW, ORDERED

72. Quadratojugal, shape: 0, L-shaped, with elongate anterior process; 1, subrectangular with long axis vertical, short, deep anterior process (Butler et al., 2008). ORDERED

73. Quadratojugal, ventral margin: 0, approaches the mandibular condyle of the quadrate; 1, well-removed from the mandibular condyle of the quadrate (Butler et al., 2008).

74. Quadrate, head: 0, partially exposed laterally; 1, 1 (Sereno and Novas, 1994; Juul, 1994; Novas, 1996; Benton, 1999; Langer and Benton, 2006; Nesbitt, 2011).

75. Quadrate shaft: 0, convex in lateral view; 1, reduced in anteroposterior width and straight in lateral view (Butler et al., 2008).

76. Quadrate, angled: 0, posteroventrally or vertical; 1, anteroventrally (Nesbitt, 2007, Nesbitt, 2011).

77. Paraquadratic foramen or notch, size: 0, absent or small; 1, large (Butler et al., 2008).

78. Paraquadratic foramen, orientation: 0, posterolateral aspect of quadrate shaft; 1, lateral aspect of quadrate or quadratojugal (Butler et al., 2008).

79. Paraquadratic foramen, position: 0, on quadrate-quadratojugal boundary; 1, located within quadratojugal (Butler et al., 2008).

80. Quadrate mandibular articulation: 0, quadrate condyles subequal in size; 1, medial condyle is larger than lateral condyle; 2, lateral condyle is larger than medial (Butler et al., 2008).

81. Paired frontals: 0, short and broad; 1, narrow and elongate (more than twice as long as wide) (Butler et al., 2008).

82. Supratemporal fenestrae, anteroposterior elongation: 0, absent, fenestrae are subcircular to oval in shape; 1, present (Butler et al., 2008).

83. Supratemporal fossa: 0, absent anterior to the supratemporal fenestra; 1, present anterior to the supratemporal fenestra, extends onto the dorsal surface of the frontal (modified from Gauthier, 1986; Novas, 1996; Nesbitt, 2011).

84. Squamosal, ventral process: 0, wider than one-quarter of its length; 1, narrower than one-quarter of its length (Yates, 2003; Langer and Benton, 2006; Nesbitt, 2011).

85. Ventral ramus of squamosal form: 0, more than half of the caudal border of the lower temporal fenestra, 1, less than half of the caudal border of the lower temporal fenestra (Langer, 2004; Pol et al., 2011b).

86. Paroccipital process: 0, extends laterally or dorsolaterally; 1, extends ventrally or ventrolaterally (Rauhut, 2003; Ezcurra, 2010; Nesbitt, 2011).

87. Paroccipital process: 0, expanded distally; 1, distal end pendent (modified from Rauhut, 2003; Ezcurra, 2010; Nesbitt, 2011).

88. Paroccipital processes, proportions: 0, short and deep (height  $\geq 1/2$  length); 1, elongate and narrow (height  $< 1/2$  length) (Butler et al., 2008).

89. Opisthotic, ventral ramus (crista interfenestralis): 0, extends further laterally than lateral-most edge of exoccipital in posterior view; 1, covered by the lateral-most edge of exoccipital in posterior view (Gower, 2002; Nesbitt, 2011).



90. Posttemporal foramen/fossa, position: 0, totally enclosed with the paroccipital process; 1, forms a notch or foramen in the dorsal margin of the paroccipital process, enclosed dorsally by the squamosal (Butler et al., 2008).
91. Exoccipital, relative positions of the exits of the hypoglossal nerve (XII): 0, aligned in a nearly anteroposterior plane; 1, aligned subvertically; 2, combined into single exit (modified from Nesbitt, 2011).
92. Exoccipital, lateral surface: 0, without subvertical crest (metotic strut); 1, with clear crest (metotic strut) lying anterior to both external foramina for hypoglossal nerve (XII); 2, with clear crest (metotic strut) present anterior to the more posterior external foramina for hypoglossal nerve (XII) (modified from Gower, 2002; Nesbitt, 2011).
93. Exoccipitals: 0, meet along the midline on the floor of the endocranial cavity (basioccipital excluded from the ventral border of the foramen magnum); 1, do not meet along the midline on the floor of the endocranial cavity (modified from Gower and Sennikov, 1996; Gower, 2002; Nesbitt, 2011).
94. Supraoccipital: 0, excluded from dorsal border of foramen magnum by mediodorsal midline contact between opposite exoccipitals; 1, contributes to border of foramen magnum (Gower, 2002, Nesbitt, 2011).
95. Supraoccipital, rugose ridge on the anterolateral edges: 0, absent; 1, present (Nesbitt, 2011).
96. Shape of the supraoccipital: 0, diamond shaped or triangular; 1, semi-lunate/crescentic (Yates, 2003; Ezcurra, 2010).
97. Supraoccipital, proportions: 0, taller than wide or as wide as tall; 1, wider than tall. NEW
98. Perilymphatic foramen: 0, with an incompletely ossified border; 1, border entirely ossified such that the ventral ramus of the opisthotic forms a perilymphatic loop incorporating a loop closure suture with itself (Gower, 2002; Nesbitt, 2011).
99. Basisphenoid, relative to the basioccipital: 0, longer than, or subequal in length to, basioccipital; 1, shorter than basioccipital (Butler et al., 2008).

100. Parabasisphenoid, ventral recess: 0, shallow; 1, well-developed. NEW
101. Parabasisphenoid, foramina for entrance of cerebral branches of internal carotid artery into the braincase positioned on the surface: 0, ventral; 1, lateral (modified from Parrish, 1993; Gower and Sennikov, 1996; Gower, 2002; Nesbitt et al., 2009c; Nesbitt, 2011).
102. Parabasisphenoid, laterally positioned foramina for entrance of cerebral branches of internal carotid artery into the braincase: 0, located anteriorly; 1, located posteriorly (modified from Parrish, 1993; Gower and Sennikov, 1996; Gower, 2002; Nesbitt et al., 2009c; Nesbitt, 2011).
103. Parabasisphenoid, recess (median pharyngeal recess, hemispherical sulcus, hemispherical fontanelle): 0, absent; 1, present (modified from Nesbitt and Norell, 2006; Nesbitt, 2011).
104. Parabasisphenoid, anterior tympanic recess on the lateral side of the braincase: 0, absent; 1, present (Makovicky and Sues, 1998; Rauhut, 2003; Nesbitt, 2011).
105. Parabasisphenoid, between basal tubera and basiptyergoid processes: 0, approximately as wide as long or wider; 1, significantly elongated, at least 1.5 times longer than wide (Rauhut, 2003; Nesbitt, 2007; Nesbitt, 2011).
106. Basal tubera, shape: 0, knob-shaped; 1, plate-shaped (Butler et al., 2008).
107. Basiptyergoid processes, orientation: 0, anterior as well as ventrolateral or anteroventral; 1, entirely ventral; 2, posteroventral (modified from Butler et al., 2008)
108. Basiptyergoid processes and basal tubera: 0, basiptyergoid processes ventrally offset relative to the basal tubera; 1, basiptyergoid process and basal tubera are horizontally aligned to one another. NEW
109. Dorsoventrally deep (deeper than 50% of snout depth) median palatal keel formed of the vomers, pterygoids and palatines: 0, absent; 1, present (Butler et al., 2008).
110. Pterygovomerine keel, length: 0, less than 50% of palate length; 1, more than 50% of palate length (Butler et al., 2008).

111. Ectopterygoid, ventral recess: 0, absent; 1, present (Gauthier, 1986; Langer and Benton, 2006; Nesbitt, 2011).
112. Ectopterygoid, body: 0, arcs; 1, straight, does not arc (modified from Nesbitt, 2011).
113. Ectopterygoid, direction of arc: 0 arcs anteriorly; 1, arcs anterodorsally (modified from Nesbitt, 2011).
114. Ectopterygoid, jugal process: 0, broad; 1, slender. NEW
115. Vestibule, medial wall: 0, incompletely ossified; 1, almost completely ossified (Gower, 2002; Nesbitt, 2011).
116. Lagenar/cochlea recess: 0, absent or short and strongly tapered; 1, present and elongated and tubular (Gower, 2002; Nesbitt, 2011).
117. Foramen for trigeminal nerve and middle cerebral vein: 0, combined and undivided; 1, at least partially subdivided by prootic; 2, fully divided (modified from Gower and Sennikov, 1996; Gower, 2002; Nesbitt, 2011). ORDERED
118. Auricular recess: 0, largely restricted to prootic; 1, extends onto internal surface of epiotic/supraoccipital (Gower, 2002; Nesbitt, 2011).
119. Cortical remodeling of surface of skull dermal bone: 0, absent; 1, present (Butler et al., 2008).
120. Predentary: 0, absent; 1, present (Sereno, 1986; Butler et al., 2007, 2008b; Nesbitt, 2011).
121. Predentary size: 0, short, posterior premaxillary teeth oppose anterior dentary teeth; 1, roughly equal in length to the premaxilla, premaxillary teeth only oppose predentary (Butler et al., 2008).
122. Predentary, rostral end in dorsal view: 0, rounded; 1, pointed (Butler et al., 2008).

123. Prementary, ventral process: 0, well-developed; 1, very reduced or absent (Butler et al., 2008).
124. Dentary, anterior extremity: 0, rounded; 1, tapers to a sharp point (Nesbitt, 2011).
125. Dentary, anterior swelling: 0, absent; 1, present, anterior end is expanded dorsoventrally just posterior to the anterior tip. NEW
126. Dentary symphysis: 0, restricted to the rostral margin of the dentary (V-shaped), or absent entirely; 1, expanded along the ventral border of the bone (spout shaped) (Serenó, 1999; Butler et al., 2008; Pol et al., 2011b).
127. Anterior half of the dentary, position of the Meckelian groove: 0, dorsoventral centre of the dentary; 1, restricted to the ventral border (Nesbitt, 2011).
128. Dentary, anterior extent of the Meckelian groove: 0, ends short of the dentary symphysis; 1, present through the dentary symphysis (Nesbitt, 2011).
129. Dentary tooth row (and edentulous anterior portion) in lateral view: 0, relatively straight; 1, anterior end downturned; 2, anterior end strongly upturned (dentary ventrally bowed) (modified from Butler et al., 2008 and Nesbitt, 2011).
130. Dorsal and ventral margins of the dentary along the posterior two thirds of the dentary tooth row: 0, converge anteriorly; 1, subparallel (modified from Butler et al., 2008).
131. Transverse groove (sulcus, external mandibular groove) running along the dentary beneath and parallel to tooth row: 0, absent; 1, present.
132. Articular, glenoid of the mandible located: 0, level with or marginally dorsal to the dorsal margin of the dentary; 1, well ventral of the dorsal margin of the dentary (modified from Gauthier, 1986; Sereno, 1999; Langer and Benton, 2006; Nesbitt, 2011; Pol et al., 2011b).
133. Maximum depth of mandible: 0, less than 150% depth of mandible beneath tooth row; 1, roughly 160% or more of the depth of mandible beneath tooth row (modified from Sereno, 1986, 1999; Butler, 2005; Irmis et al., 2007; Butler et al., 2008; Nesbitt, 2011).

134. Anterodorsal margin of coronoid process formed by posterodorsal process of dentary: 0, absent; 1, present (Butler et al., 2008).
135. Splenial, foramen in the ventral part: 0, absent; 1, present (modified from Rauhut, 2003; Langer and Benton, 2006; Smith et al., 2007; Nesbitt, 2011).
136. External mandibular fenestra, situated on dentary-surangular-angular boundary: 0, present; 1, absent (Butler et al., 2008).
137. External mandibular fenestra between the surangular, angular and dentary, proportions: 0, small, rounded or elliptical with anteroposterior length is less than 4 times the dorsoventral depth; 1, fenestra is a greatly elongate ellipse, length is greater than 4 times the dorsoventral depth. NEW
138. Small fenestra positioned dorsally on the surangular-dentary joint: 0, absent; 1, present (Butler et al., 2008).
139. Foramen located on the dorsal (and sometimes lateral) face of the surangular (surangular foramen): 0, present; 1, absent. NEW
140. Surangular foramen: 0, both foramen (anterior, dorsally positioned and posterior, laterally positioned) remain open; 1 only the foramen on the dorsal surface of the surangular, anterior to or at the point of maximum mandibular depth remains open; 2, only the foramen located laterally, posterior to the point of maximum mandibular depth remains open. NEW
141. Ridge or process on lateral surface of surangular, anterior to jaw suture: 0, absent or very poorly developed; 1, present, strong anteroposteriorly extended ridge; 2, present, dorsally directed finger-like process (Butler et al., 2008).
142. Anteroposteriorly extending groove on the dorsal surface of the surangular (dorsal surface formed by medial inflection of the lateral surangular): 0, absent; 1, present. NEW
143. Retroarticular process: 0, elongate; 1, rudimentary or absent (Butler et al., 2008).
144. Retroarticular process in lateral and dorsal view: 0, does not taper caudally, 1, tapers caudally (Yates, 2003; Pol et al., 2011b).

145. Retroarticular process, upturn: 0, present and strong, retroarticular forms nearly a right angle with the rest of the mandible; 1, present and subtle, retroarticular is slightly upturned at its distal end; 2, absent, retroarticular extends straight out from the caudal part of the mandible, or turns slightly downward (new). ORDERED
146. Mandibular osteoderm: 0, absent; 1, present (Butler et al., 2008).
147. Dentary teeth: 0, present along almost entire length of the dentary; 1, absent in the anterior portion; 2, completely absent (modified from Parrish, 1994; Parker, 2007; Nesbitt, 2011).
148. Number of dentary teeth: 0, 17 or fewer; 1, 18 or more (Wilson and Sereno, 1998; Pol et al., 2011b).
149. First dentary tooth: 0, lies at the extreme rostral end of the dentary; 1, is inset a short distance from the rostral tip of the dentary (Sereno, 1999; Pol et al., 2011b).
150. Premaxillary teeth: 0, present; 1, absent, premaxilla edentulous (Butler et al., 2008).
151. Premaxillary teeth, number: 0, six or more; 1, five; 2, four; 3, three; 4, two; 5, one or none (modified from Butler et al., 2008).
152. Premaxillary teeth, crown expanded above root: 0, crown is unexpanded mesiodistally above root, no distinction between root and crown is observable; 1, crown is at least moderately expanded above root (Butler et al., 2008).
153. Premaxillary teeth increase in size posteriorly: 0, absent; 1, present, posterior premaxillary teeth are significantly larger in size than anterior teeth (Butler et al., 2008).
154. Premaxillary teeth size: 0, anterior premaxillary teeth are smaller than most maxillary teeth; 1, anterior premaxillary teeth are subequal to maxillary teeth; 2, anterior premaxillary teeth are enlarged relative to maxillary teeth. NEW
155. Premaxillary caniniform tooth, distinct from anterior premaxillary teeth: 0, absent; 1, present, squat caniniform (greater in diameter than in apicobasal height); 2, present, long caniniform (greater in apicobasal height than in diameter). NEW

156. Maxillary and dentary crowns, shape: 0, bladelike, with continuous mesial and distal edges; 1, subtriangular or 'diamond shaped', with a distinct kinks present in mesial and distal edges (modified from Sereno, 1986; Butler et al., 2008; Nesbitt, 2011).
157. Maxillary and dentary crowns, dimensions: 0, apicobasally taller than they are mesiodistally wide; 1, apicobasally shorter than they are mesiodistally wide. NEW
158. Enamel on maxillary/dentary teeth: 0, symmetrical; 1, asymmetrical (Butler et al., 2008).
159. Apicobasally extending ridges on maxillary/dentary teeth: 0, absent; 1, present (Butler et al., 2008).
160. Apicobasally extending ridges on lingual/labial surfaces of maxillary/dentary crowns confluent with marginal denticles: 0, absent; 1, present (Butler et al., 2008).
161. Tooth implantation, teeth ankylosed into the alveoli (ankylotheodont): 0, absent (free at the base of tooth); 1, present (modified from Gauthier, 1984; Benton and Clark, 1988; Benton, 1990; Bennett, 1996; Nesbitt et al., 2009c; Nesbitt, 2011).
162. Prominent primary ridge on labial side of maxillary teeth: 0, absent; 1, present (Butler et al., 2008).
163. Prominent primary ridge on lingual side of dentary teeth: 0, absent; 1, present (Butler et al., 2008).
164. Position of maxillary/dentary primary ridge: 0, centre of the crown surface, giving the crown a relatively symmetrical shape in lingual/labial view; 1, offset, giving crown asymmetrical appearance (Butler et al., 2008).
165. Labial side of maxillary/dentary teeth, profile: 0, evenly convex in mesiodistal aspect (D-shaped profile), 1, with greater labiolingual expansion at the base of the tooth. NEW
166. Moderately developed lingual expansion of crown (cingulum) on maxillary/ dentary teeth: 0, absent; 1, present (Sereno, 1986; Butler et al., 2008; Nesbitt, 2011).

167. Dentition: 0, homodont; 1, slightly heterodont, with small observable changes across tooth rows; 2, markedly heterodont, clearly distinct types of teeth present (modified from Parrish, 1993; Nesbitt, 2011). ORDERED
168. Heterodont dentary dentition: 0, no substantial heterodonty is present in dentary dentition; 1, single, enlarged, caniform anterior dentary tooth, crown is not mesiodistally expanded above root; 2, multiple anterior dentary teeth are recurved but are not enlarged relative to other dentary teeth; 3 multiple anterior dentary teeth are recurved and are enlarged relative to other dentary teeth (modified from Butler et al., 2008).
169. Maxillary/dentary tooth, serrations: 0, absent; 1, present as small fine knifelike serrations; 2, present and enlarged and coarser (lower density) denticles. (modified from Gauthier et al., 1988; Juul, 1994; Dilkes, 1998; Irmis et al., 2007; Butler et al., 2008; Nesbitt, 2011). ORDERED
170. Distribution of the serrations along the mesial and distal carinae of the teeth: 0, extended along most of the length of the crown; 1, restricted to the upper half of the crown (Yates, 2003; Ezcurra, 2010).
171. Peg-like tooth located anteriorly within dentary, lacks recurvature and denticles, strongly reduced in size: 0, absent; 1, present (Butler et al., 2008).
172. Alveolar foramina ('special foramina') medial to maxillary/ dentary tooth rows: 0, present; 1, absent (Butler et al., 2008).
173. Recurvature in premaxillary teeth: 0, present, 1, absent. NEW
174. Recurvature in majority of maxillary and dentary teeth: 0, strong recurvature present; 1, weak recurvature present; 2, recurvature absent (modified from Butler et al., 2008) ORDERED
175. Maxillary teeth, posterior cutting edge of posterior maxillary teeth: 0, concave or straight; 1, convex (modified from Sues et al., 2003; Clark et al., 2004; Nesbitt, 2011).
176. Medial or lateral overlap of adjacent crowns in maxillary and dentary teeth: 0, absent; 1, present (Serenio, 1986; Butler et al., 2008; Nesbitt, 2011).
177. Tooth crown, maxillary/dentary teeth: 0, not mesiodistally expanded; 1, mesiodistally expanded above root in cheek teeth (Serenio, 1986; Butler et al., 2008; Nesbitt, 2011).



178. Extensive planar wear facets across multiple maxillary/dentary teeth: 0, absent; 1, present (Weishampel and Witmer, 1990; Nesbitt, 2011; Han et al., 2012).
179. Position of maximum apicobasal crown height in dentary/maxillary tooth rows: 0, anterior portion of tooth row; 1, central portion of tooth rows; 2, posterior portion of tooth rows (Gauthier, 1986; Butler et al., 2008; Pol et al., 2011b).
180. Conical, often unserrated tooth crowns: 0, absent, 1, present together with serrated crowns, 2, encompasses all dental elements of maxilla and dentary (new). ORDERED
181. Palatal teeth present on palatal process of the pterygoid: 0, present; 1, absent (Juil, 1994; Gower and Sennikov, 1997; Nesbitt et al., 2009c; Nesbitt, 2011).
182. Teeth on transverse processes of pterygoids: 0, present; 1, absent (Gauthier, 1984; Juil, 1994; Bennett, 1996; Gower and Sennikov, 1997; Nesbitt et al., 2009c; Nesbitt, 2011).
183. Close-packing and quicker replacement eliminates spaces between alveolar border and crowns of adjacent functional teeth: 0, absent; 1, present (Butler et al., 2008).
184. Anterior dentary teeth, orientation: 0, vertical or inclined posteriorly; 1, inclined anteriorly (procumbent).
185. Line from the mesiodistal centre of the base of the tooth to the tip of tooth curves anteriorly in dentary teeth: 0, absent; 1, present (modified from Kammerer et al., 2012).
186. Length of the atlantal intercentrum: 0, greater than that of the axial intercentrum; 1, shorter than that of the axial intercentrum (Yates and Kitching, 2003; Pol et al., 2011b).
187. Axis, dorsal margin of the neural spine: 0, expanded posterodorsally; 1, arcs dorsally, where the anterior portion height is equivalent to the posterior height (Nesbitt, 2011).
188. Cervical vertebrae, deep recesses on the anterior face of the neural arch, lateral to the neural canal (prechonos of Welles, 1984): 0, absent; 1, present (Nesbitt, 2011).

189. Epiphyses on anterior (postaxial) cervicals: 0, absent; 1, present (modified from Gauthier, 1986; Novas 1996; Langer and Benton, 2006; Butler et al., 2008; Nesbitt, 2011).
190. Epiphyses: 0, absent in posterior cervical vertebrae (6–9); 1, present in posterior cervical vertebrae (6–9) (Serenó et al., 1993; Langer and Benton, 2006; Nesbitt, 2011).
191. Epiphyses overhanging the rear margin of the postzygapophyses: 0, absent, epiphyses do not overhang the postzygapophyses in any postaxial cervical vertebrae; 1, present in at least some postaxial cervical vertebrae (modified from Yates, 2003; Pol et al., 2011b).
192. Third cervical vertebra, centrum length: 0, subequal to the axis centrum; 1, longer than the axis centrum (Gauthier, 1986; Langer and Benton, 2006; Nesbitt, 2011).
193. Cervicals 4–9, form of central surfaces: 0, amphicoelous; 1, at least slightly opisthocoelous or heterocoelous (Butler et al., 2008).
194. Cervical number: 0, seven/eight; 1, nine; 2, ten or more (Butler et al., 2008).
195. Anterior to middle cervical vertebrae, diapophysis and parapophysis: 0, well separated; 1, nearly touching (Nesbitt, 2011).
196. Anterior cervical vertebrae, neural arch, posterior portion ventral to the postzygapophysis: 0, smooth posteriorly or has a shallow fossa; 1, with a deep excavation (modified from Langer and Benton, 2006; Nesbitt, 2011).
197. Cervical vertebrae, pneumatic features (pleurocoels) in the anterior portion of the centrum: 0, absent; 1, present as fossae; 2, present as foramina (modified from Holtz, 1994; Rauhut, 2003; Smith et al., 2007; Nesbitt, 2011). ORDERED
198. Cervical vertebrae, rimmed depression on the posterior part of the centrum: 0, absent; 1, present (modified from Gauthier, 1986; Rauhut, 2003; Nesbitt, 2011).
199. Elongation of cervical centrum (cervicals 3–5): 0, less than 3.0 times the centrum height, 1, 3.0–4.0 times the centrum height, 2, >4.0 times the centrum height (Upchurch, 1998; Pol et al., 2011b). ORDERED

200. Cervical vertebrae, distal end of neural spines: 0, laterally expanded in the middle of the anteroposterior length; 1, expansion absent. NEW
201. Posterior cervical and/or dorsal vertebrae, hyposphene-hypantrum accessory intervertebral articulations: 0, absent; 1, present (Gauthier, 1986; Juul, 1994; Benton, 1999; Rauhut, 2003; Langer and Benton, 2006; Weinbaum and Hungerbühler, 2007; Nesbitt, 2011).
202. Hyposphene in the cervical and/or dorsal vertebrae, height: 0, less than the height of the neural canal; 1, equal to or greater than the height of the neural canal (modified from Gauthier, 1986; Yates, 2007; Ezcurra, 2010).
203. Prezygaodiapophyseal lamina on the cervical vertebrae: 0, absent; 1, present. NEW
204. Postzygaodiapophyseal lamina on cervical neural arches 4 to 8: 0, absent; 1, present (Yates, 2003; Ezcurra, 2010; Pol et al., 2011b).
205. Laminae of the cervical neural arches 4-8: 0, well developed, tall laminae; 1, weakly developed, low ridges (Wilson and Sereno, 1998; Ezcurra, 2010).
206. Angle formed between pre- and postzygapophyses on anterior-to-middle cervical vertebrae: 0, very large, around 40 degrees, or over; 1, large, around 30 degrees; 2, small, around 20 degrees (new). ORDERED
207. Ventral keels on cranial cervical centra: 0, present, 1, absent (Upchurch, 1998; Pol et al., 2011b).
208. Ventral keels on the vertebrae at the cervicodorsal transition: 0, absent; 1, present (Rauhut, 2003; Ezcurra, 2010).
209. Cervical ribs: 0, slender and elongated; 1, short and stout (Gauthier, 1986; Benton and Clark, 1988; Juul, 1994; Benton, 1999; Nesbitt, 2011).
210. Dorsal vertebrae, neural spine lateral expansion of the distal end: 0, absent; 1, present with a flat dorsal margin (spine table); 2, present with a rounded dorsal margin (Nesbitt, 2011).

211. Dorsal vertebrae (mid- to posterior dorsal), neural spine anteroposterior expansion of distal end: 0, absent; 1, present, distal end of neural spine is anteroposteriorly longer than base of neural spine. NEW
212. Posterior dorsal vertebrae, neural spine inclination: 0, anteriorly inclined; 1, vertical or posteriorly inclined. NEW
213. Parapophyses contact with the centrum in vertebrae caudal to the twelfth presacral element: 0, do not contact, 1, contact (Langer, 2004; Pol et al., 2011b).
214. Dorsals, number: 0, 12–14; 1, 15; 2, 16 or more (modified from Butler et al., 2008). ORDERED
215. Sacrals, number: 0, two; 1, three; 2, four/five; 3, six or more (Butler et al., 2008). ORDERED
216. Posterior sacral ribs are longer than anterior sacral ribs: 0, absent; 1, present, marginally longer; 2, present, considerably longer (modified from Butler et al., 2008).
217. Sacral centra: 0, separate; 1, at least partially co-ossified (modified from Nesbitt, 2011).
218. Sacral vertebrae, prezygapophyses and complimentary postzygapophyses: 0, separate; 1, co-ossified (Nesbitt, 2011).
219. Fusion of the sacral neural spines: 0, absent; 1, present. NEW
220. Sacral vertebrae, centra articular rims: 0, present in sacrum; 1, absent or nearly obliterated (modified from Nesbitt, 2007, 2011).
221. “Insertion” of a sacral vertebra between the first and second primordial sacral vertebrae: 0, absent; 1, present (Nesbitt, 2011).
222. Number of dorsosacral vertebrae: 0, none; 1, one; 2, two (Gauthier, 1986; Yates, 2007; Ezcurra, 2010). ORDERED

223. Sacral ribs: 0, almost entirely restricted to a single sacral vertebra; 1, shared between two sacral vertebrae (Nesbitt, 2011).
224. First primordial sacral, articular surface of sacral rib: 0, circular; 1, C-shaped in lateral view; 2, rectangular (modified from Langer and Benton, 2006; Nesbitt, 2011).
225. Possession of a caudosacral vertebra: 0, absent; 1, present. NEW
226. Length of first caudal centrum: 0, greater than its height; 1, much less than its height (Yates, 2003; Ezcurra, 2010).
227. Anterior caudal vertebrae, neural spines: 0, up to 50% taller than the centrum; 1, more than 50% taller than the centrum (Butler et al., 2008).
228. Length of base of the proximal caudal neural spines: 0, greater than half the length of the neural arch, 1, less than half the length of the neural arch (Gauthier 1986, Yates and Kitching, 2003; Ezcurra, 2010).
229. Length of midcaudal centra: 0, greater than twice the height of their proximal faces; 1, less than twice the height of their proximal faces (Yates and Kitching, 2003; Pol et al., 2011b).
230. Distal caudal vertebrae, prezygapophyses: 0, not elongated; 1, elongated beyond the anterior face of the centrum (modified from Gauthier, 1986; Rauhut, 2003; Nesbitt, 2007; Nesbitt, 2011).
231. Elongated prezygapophyses of the distal caudals: 0, elongated less than  $\frac{1}{4}$  of the length of the adjacent centrum; 1, elongated more than  $\frac{1}{4}$  of the length of the adjacent centrum (modified from Gauthier, 1986; Rauhut, 2003; Nesbitt, 2007; Nesbitt, 2011).
232. Position of postzygapophyses in proximal caudal vertebra: 0, protruding with an interpostzygapophyseal notch visible in dorsal view; 1, placed on either side of the caudal end of the base of the neural spine without any interpostzygapophyseal notch (Yates and Kitching, 2003; Pol et al., 2011b).
233. Chevron shape: 0, rod-shaped, often with a slight distal expansion; 1, strongly expanded distally, triangular or 'boat' shaped (modified from Butler et al., 2008).

234. Length of the longest chevron: 0, less than the length of the preceding centrum, 1, greater than the length of the preceding centrum (Yates and Kitching, 2003; Pol et al., 2011b).
235. Gastralia: 0, present; 1, absent (Butler et al., 2008).
236. Gastralia, form: 0, forming extensive ventral basket with closely packed elements; 1, elements well separated (modified from Nesbitt, 2011).
237. Ossified clavicles: 0, absent; 1, present (Butler et al., 2008).
238. Clavicles: 0, unfused; 1, fused into a furcula (modified from Gauthier, 1986; Sereno, 1991; Benton, 1999; Benton and Walker, 2002; Nesbitt, 2011).
239. Sternal plates: 0, absent; 1, present (modified from Butler et al., 2008).
240. Proportions of humerus and scapula: 0, scapula longer or subequal to the humerus; 1, humerus longer than the scapula (Butler et al., 2008).
241. Scapula, blade height versus distal width: 0, less than 3 times distal width; 1, more than 3 times distal width (Sereno, 1999).
242. Minimum width of scapula: 0, less than or equal to 20% of its length; 1, more than 20% of its length (Gauthier, 1986; Ezcurra, 2010).
243. Scapula, blade-shape: 0, strongly expanded distally; 1, weakly expanded, near parallel-sided (Butler et al., 2008).
244. Scapula acromion shape: 0, weakly developed or absent; 1, well-developed spine-like (Butler et al., 2008).
245. Orientation of dorsal margin of the acromion process of the scapula: 0, posteroventrally, forming an acute angle with the dorsoventral axis of the scapula, 1, posteriorly or subhorizontally, forming an obtuse or right angle with the dorsoventral axis of the scapula (Novas, 1996; Pol et al., 2011b).

246. Scapulocoracoid, anterior margin: 0, distinct notch between the two elements; 1, uninterrupted edge between the two elements (Parrish, 1993; Benton, 1999; Nesbitt, 2011).
247. Coracoid: 0, subcircular in lateral view; 1, with postglenoid process (notch ventral to glenoid) (Nesbitt, 2011).
248. Coracoid, posteroventral edge, deep groove: 0, absent; 1, present (Nesbitt, 2011).
249. Coracoid, posteroventral portion: 0, smooth; 1, possesses a “swollen” tuber (biceps tubercle, posteroventral process) (Nesbitt, 2011).
250. Glenoid, orientation: 0, posterolaterally; 1, directed posteroventrally (Fraser et al., 2002; Nesbitt, 2011).
251. Humerus/femur ratio: 0, roughly equal to or less than 0.6; 1, greater than 0.6 but less than 0.8; 2, greater than 0.8 (modified from Gauthier, 1986). ORDERED
252. Deltopectoral crest: 0, less than 30% the length of the humerus; 1, more than 30% the length of the humerus (Bakker and Galton, 1974; Benton, 1990; Juul, 1994; Novas, 1996; Benton, 1999).
253. Humerus, apex of deltopectoral crest situated at a point corresponding to: 0, less than 30% down the length of the humerus; 1, more than or equal to 30% down the length of the humerus but less than 50% down the length of the humerus; 2, more than 50% down the length of the humerus (modified from Bakker and Galton, 1974; Benton, 1990; Juul, 1994; Novas, 1996; Benton, 1999, Nesbitt, 2011).
254. Deltopectoral crest orientation: 0, slants at <60 to the transverse axis of the distal condyles, 1, perpendicular to the transverse axis of the distal condyles (Sereno, 1999; Pol et al., 2011b).
255. Deltopectoral crest form/development: 0, rudimentary, is at most a thickening of the humerus; 1, well-developed, projects as a distinct flange (modified from Butler et al., 2008).
256. Humeral shaft in anterior/posterior view: 0, relatively straight; 1, bowed ventrally (new).

257. Head of humerus is separated from prominent medial tubercle on proximal surface by a groove: 0, absent; 1, present (Han et al., 2012).
258. Humerus, proximal articular surface: 0, continuous with the deltopectoral crest; 1, separated by a gap from the deltopectoral crest (Nesbitt, 2011).
259. Humerus, distinct fossa on posterodorsal surface, just below the proximal edge: 0, absent; 1, present (new).
260. Humerus, distal end width: 0, narrower or equal to 30% of humerus length; 1, greater than 30% of humerus length (Langer and Benton, 2006).
261. Maximum transverse expansion of the distal end of the humerus: 0, greater than 50% of the maximum transverse expansion of the proximal humerus; 1, less than or equal to 50% of the maximum transverse expansion of the proximal humerus (new).
262. Ulna, lateral tuber (radius tuber) on the proximal portion: 0, absent; 1, present (Nesbitt, 2011).
263. Olecranon process on proximal ulna: 0, absent; 1, present (modified from Wilson and Sereno, 1998; Ezcurra, 2010).
264. Olecranon process: 0, not greatly enlarged; 1, greatly enlarged as a single ossification; 2, greatly enlarged with a separate ossification forming a strongly striated proximoanterior portion (modified from Wilson and Sereno, 1998; Ezcurra, 2010).
265. Radial fossa, bounded by an anterolateral process, on proximal ulna: 0, absent; 1, present (modified from Wilson and Sereno, 1998; Ezcurra, 2010).
266. Form of radial fossa: 0, shallow; 1, deep (new).
267. Radius, length: 0, longer than 80% of humerus length; 1, shorter than 80% of humerus length (Langer and Benton, 2006).
268. Proximal carpals (radiale, ulnare): 0, equidimensional; 1, elongate (Benton and Clark, 1988; Parrish, 1993; Benton and Walker, 2002; Clark et al., 2004; Nesbitt, 2011).



269. Proximal width of the first metacarpal respect to its length: 0, less than 65% of its length, 1, 65%-80% of its length, 2, greater than 80% of its length, 3: broader proximally than long (Sereno, 1999; Pol et al., 2011b). ORDERED
270. First distal carpal: 0, is narrower transversely than metacarpal I, 1, is subequal, or greater, in transverse width compared to metacarpal one (Sereno, 1999; Pol et al., 2011b).
271. Second distal carpal: 0, completely covers the proximal end of metacarpal II; 1, does not completely cover the proximal end of metacarpal II (Yates and Kitching, 2003; Ezcurra, 2010).
272. Manual length (measured as the average length of digits I–III): 0, accounts for less than 0.3 of the total length of humerus plus radius; 1, more than 0.3 but less than 0.4 of the total length of humerus plus radius; 2, more than 0.4 of the total length of humerus plus radius (modified from Gauthier, 1986; Langer and Benton, 2006; Nesbitt, 2011). ORDERED
273. Metacarpals, proximal ends: 0, overlap; 1, abut one another without overlapping (Sereno and Wild, 1992; Clark et al., 2000; Olsen et al., 2000; Benton and Walker, 2002; Sues et al., 2003; Clark et al., 2004; Butler et al., 2008; Nesbitt, 2011).
274. Metacarpals I and V: 0, both substantially shorter in length than metacarpal III; 1, only metacarpal I longer than or subequal to metacarpal III; 2, only metacarpal V longer than or subequal to metacarpal III; 3, both are longer than or subequal to metacarpal III (modified from Butler et al., 2008).
275. Distal carpal V: 0, present; 1, absent (Sereno, 1999; Langer and Benton, 2006; Nesbitt, 2011).
276. Distal carpal V: 0, smaller than or roughly equal in size to other distal carpals; 1, greater in size than other distal carpals (modified from Yates, 2007; Ezcurra, 2010).
277. Penultimate phalanx of the second and third fingers: 0, shorter than or equal to the first phalanx; 1, longer than the first phalanx (modified from Butler et al., 2008).
278. Metacarpal V: 0, present; 1, absent. NEW

279. Manual digit V: 0, possesses one or more phalanges; 1, phalanges absent (modified from Bakker and Galton, 1974; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
280. Extensor pits on the dorsal surface of the distal end of metacarpals and manual phalanges: 0, absent or poorly developed; 1, deep, well-developed (Serenó et al., 1993; Langer and Benton, 2006; Butler et al., 2008; Nesbitt, 2011).
281. Manual unguals strongly recurved with prominent flexor tubercle: 0, present; 1, absent (modified from Butler et al., 2008).
282. Metacarpal I, width at the middle of the shaft accounts for: 0, less than 0.35 of the total length of the bone; 1, more than 0.35 of the total length of the bone (modified from Bakker and Galton, 1974; Langer and Benton, 2006; Nesbitt, 2011).
283. Digit I with metacarpal: 0, longer than the ungual; 1, subequal or shorter than the ungual (Serenó, 1999; Langer and Benton, 2006; Nesbitt, 2011).
284. Manual digit I, first phalanx: 0, is not the longest non-ungual phalanx of the manus; 1, is the longest non-ungual phalanx of the manus (Gauthier, 1986; Langer and Benton, 2006; Nesbitt, 2011).
285. Metacarpal I, distal condyles: 0, approximately aligned or slightly offset; 1, lateral condyle strongly distally expanded relative to medial condyle (modified from Bakker and Galton, 1974, Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
286. Ventrolateral twisting of the transverse axis of the distal end of the first phalanx of manual digit one relative to its proximal end: 0, absent, 1, present proximodorsal lip aligned with dorsal margin of medial distal condyle, 2, present proximodorsal lip aligned with central region of medial ligament pit of the distal condyle (Serenó, 1999; Pol et al., 2011b; Otero et al., 2015). ORDERED
287. Metacarpal II: 0, shorter than metacarpal III; 1, equal to or longer than metacarpal III (Gauthier, 1986; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
288. Manual digits I–III: 0, blunt unguals on at least digits II and III; 1, trenchant unguals on digits I–III (Gauthier, 1986; Juul, 1994; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011).

289. Manual digit IV: 0, five or four phalanges; 1, three or two phalanges; 2, one phalanx; 3, phalanges absent (Gauthier, 1986; Benton and Clark, 1988; Sereno et al., 1993; Novas, 1996; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011). ORDERED
290. Metacarpal IV, shaft width: 0, about the same width as that of metacarpals I–III; 1, significantly narrower than that of metacarpals I–III (modified from Sereno et al., 1993; Langer and Benton, 2006; Nesbitt, 2011).
291. Metacarpals IV and V, position: 0, level with metacarpals I–III; 1, ventral to metacarpals I–III (Sereno, 1993; Ezcurra, 2010).
292. Acetabulum: 0, completely closed; 1, open to at least some degree (modified from Butler et al., 2008).
293. Ilium, anterior (preacetabular, cranial) process: 0, short and does not extend anterior to the pubic peduncle; 1, long and extends anterior to the pubic peduncle (modified from Galton, 1976; Benton, 1985; Sereno, 1986; Juul, 1994; Gower, 2000; Hutchinson, 2001a; Langer and Benton, 2006; Nesbitt and Norell, 2006; Butler et al., 2008b; Nesbitt, 2011).
294. Ilium, relative lengths of anterior (preacetabular, cranial) and posterior processes: 0, anterior process much shorter than the posterior process of the ilium; 1, anterior process subequal or longer than the posterior process of the ilium (modified from Galton, 1976; Benton, 1985; Sereno, 1986; Juul, 1994; Gower, 2000; Hutchinson, 2001a; Langer and Benton, 2006; Nesbitt and Norell, 2006; Butler et al., 2008b; Nesbitt, 2011).
295. Shape of preacetabular process: 0, rounded/rectangular, blunt profile, 1, triangular and pointed; 2, elongated and strap-like; 3, expanded dorsoventrally towards its anterior end producing a hatchet-shaped profile (i.e. possesses an anteroventral lobe) (Sereno, 1999; Pol et al., 2011b).
296. Preacetabular process, length: 0, less than 50% of the length of the ilium; 1, more than 50% of the length of the ilium (Butler et al., 2008).
297. Length of the preacetabular process of the ilium: 0, less than twice its depth, 1, greater than twice its depth (Yates and Kitching, 2003; Pol et al., 2011b).
298. Dorsal margin of preacetabular process and dorsal margin of ilium above acetabulum: 0, narrow, not transversely expanded; 1, dorsal margin is transversely expanded to form a narrow shelf (Butler et al., 2008).

299. Ilium, dorsal portion: 0, height about the same or shorter than the distance from the dorsal portion of the supraacetabular rim to the pubis-ischium contact; 1, expanded dorsally, height markedly taller than the dorsal portion of the supraacetabular rim to the pubis-ischium contact (Nesbitt, 2011).

300. In dorsal view preacetabular process of the ilium expands mediolaterally towards its distal end: 0, absent; 1, present (Butler et al., 2008).

301. Dorsal margin of the ilium in lateral view: 0, relatively straight or convex; 1, concave (saddle-shaped), postacetabular process is upturned (modified from Butler et al., 2008).

302. Shape of the caudal margin of the postacetabular process of the ilium: 0, rounded or bluntly pointed, 1, square ended (Yates, 2003; Pol et al., 2011b).

303. Ilium, distinct fossa present for the attachment of the caudifemoralis brevis muscle (brevis shelf): 0, absent; 1, present as an embankment on the lateral side of the posterior portion of the ilium; 2, present, not visible in lateral view and is in the form of a fossa on the dorsal margin of the ilium and/or the ventral surface of postacetabular process (modified from Gauthier and Padian, 1985; Gauthier, 1986; Juul, 1994; Novas, 1996; Benton, 1999; Hutchinson, 2001a; Butler et al., 2008; Nesbitt, 2011). ORDERED

304. Ilium, ridge connecting the posterior portion of the supraacetabular rim to the posterior portion of the ilium: 0, absent; 1, present (modified from Langer and Benton, 2006; Nesbitt, 2011).

305. Ilium, ridge (or buttress) extending from the middle of the supraacetabular crest to the lateral edge of the preacetabular process: 0, absent; 1, present, low and rounded swelling; 2, present, pronounced and sharp (buttress) (new). ORDERED

306. Ilium, ventral margin of the acetabulum: 0, convex; 1, straight; 2, concave (Bakker and Galton, 1974; Gauthier and Padian, 1985; Gauthier, 1986; Juul, 1994; Novas, 1996; Benton, 1999; Fraser et al., 2002; Langer and Benton, 2006; Nesbitt, 2011).

307. Length of the postacetabular process as a percentage of the total length of the ilium: 0, more than 35%; 1, 35%-25%; 2, 20% or less (Butler et al., 2008). ORDERED

308. Medioventral acetabular flange of ilium, closes the acetabulum: 0, present, partially or fully closes the acetabulum; 1, absent (modified from Butler et al., 2008).
309. Ilium, ischiadic peduncle: 0, part of the main body of ilium, continuous with distal portion of the acetabular wall; 1, posterior portion is distinct from the main body of the ilium and the acetabular wall, is a ventrally/posteroventrally extending body. NEW
310. Ilium, ischiadic peduncle orientation: 0, mainly vertical in lateral aspect; 1, well expanded posteriorly to the anterior margin of the postacetabular embayment (Langer and Benton, 2006; Butler et al., 2008; Nesbitt, 2011).
311. Supra-acetabular 'crest' or 'flange': 0, present; 1, absent (Butler et al., 2008).
312. Ilium, supraacetabular crest (supraacetabular rim): 0, projects laterally or ventrolaterally; 1, projects ventrally (Gauthier, 1986; Nesbitt, 2011).
313. Supraacetabular crest of ilium: 0, not extended along (only at the base of) the pubic peduncle; 1, extended along the pubic peduncle as a faint ridge; 2, extended along the full length of the pubic peduncle and contacts the distal end as a well-developed crest (Ezcurra, 2010).  
ORDERED
314. Pubic peduncle of ilium: 0, longer in length than ischiadic peduncle; 1, shorter in length than ischiadic peduncle (modified from Butler et al., 2008).
315. Length of the pubic peduncle of ilium: 0, greater than twice the craniocaudal width of its distal end, 1, less than twice the craniocaudal width of its distal end (when excluding contribution of medioventral acetabular wall to craniocaudal width) (modified from Sereno, 1999; Ezcurra, 2010; Pol et al., 2011b).
316. Heavy reduction in dorsoventral depth of the ischiadic peduncle of the ilium, peduncle is almost completely lost: 0, absent; 1, present. NEW
317. Ilium, acetabular antitrochanter: 0, absent; 1, present (Sereno and Arcucci, 1994; Novas, 1996; Benton, 1999; Fraser et al., 2002; Irmis et al., 2007; Nesbitt, 2011; Nesbitt, 2011).
318. Ilium, extensive, highly rugose areas on the dorsal and lateral surfaces of the pre- and postacetabular processes: 0, absent; 1, present. NEW

319. Ischium, shape of shaft: 0, relatively straight; 1, curved along length (modified from Butler et al., 2008).
320. Ischium-pubis, contact: 0, present and extended ventrally; 1, present and reduced to a thin proximal contact; 2, absent (modified from Benton and Clark, 1988; Novas, 1996; Nesbitt, 2011).
321. Ischial shaft, cross-section: 0, compressed mediolaterally into thin sheet (rectangular); 1, subcircular/ovoid and bar-like (rod-like); 2, triangular or D-shaped (new).
322. Ischial shaft: 0, tapers distally; 1, expands weakly, or is parallel-sided, distally; 2, distally expanded into a distinct 'foot' or 'boot' (modified from Butler et al., 2008). ORDERED
323. Ischium, obturator process: 0, absent; 1, confluent with the pubic peduncle (obturator plate); 2, offset from the pubic peduncle (modified from Gauthier, 1986; Novas, 1993; Rauhut, 2003; Nesbitt, 2011).
324. Ischium, proximal portion of the ventral margin: 0, continuous ventral margin; 1, notch present; 2, abrupt change in angle between the proximal end and the shaft (modified from Sereno et al., 1996; Rauhut, 2003; Nesbitt, 2011).
325. Ischium, proximal articular surfaces: 0, articular surfaces with the ilium and the pubis continuous; 1, articular surfaces with the ilium and the pubis continuous but separated by a fossa; 2, articular surfaces with the ilium and the pubis separated by a large, nonarticulating concave surface (modified from Irmis et al., 2007; Nesbitt, 2011). ORDERED
326. Ischium length: 0, about the same length or shorter than the dorsal margin of iliac blade; 1, longer than the dorsal margin of iliac blade (Juil, 1994; Nesbitt et al., 2009c; Nesbitt, 2011).
327. Groove on the dorsal margin of the ischium: 0, absent; 1, present (Butler et al., 2008).
328. Distinct obturator process of ischium (when separated from the pubic process of the ischium), form: 0, present as a rounded expansion of ventral margin; 1, present as distinct tab ('tab-shaped') (modified from Butler et al., 2008).

329. Ischium, medial contact with antimere: 0, restricted to the medial edge; 1, extensive contact but the dorsal margins are separated; 2, extensive contact and the dorsal margins contact each other (Nesbitt, 2011).

330. Ischium, cross section of the distal portion: 0, platelike; 1, rounded or semicircular; 2, subtriangular or D-shaped (modified from Sereno, 1999; Langer and Benton, 2006; Irmis et al., 2007; Yates, 2007; Ezcurra, 2010; Nesbitt, 2011).

331. Ischial symphysis, length: 0, ischium forms a median symphysis with the opposing blade along at least 50% of its length; 1, ischial symphysis present distally only (elongate interischial fenestra) (Yates, 2003; Butler et al., 2008; Pol et al., 2011b).

332. Pubis, orientation: 0, anteroventral; 1, rotated posteroventrally (opisthopubic) (Sereno, 1986; Butler et al., 2008; Nesbitt, 2011).

333. Shaft of pubis (postpubis), shape in cross-section: 0, blade-shaped; 1, rod-like; 2, rod-like, but with a tapering medial margin (teardrop-shaped) (modified from Butler et al., 2008). ORDERED

334. Shaft of pubis (postpubis), length: 0, longer than or approximately equal in length to the ischium; 1, reduced, extends two-thirds to one-half of the length of the ischium; 2, splint-like (modified from Butler et al., 2008). ORDERED

335. Pubic plate length: 0, less than 40% of the pubic shaft length; 1, more than 40% of the pubic shaft length (Pol and Powell, 2007).

336. Pubic shaft, shape: 0, posteriorly bowed; 1, relatively straight; 2, anteriorly bowed (modified from Sereno, 1999; Ezcurra and Novas, 2007; Ezcurra, 2010).

337. Body of pubis, size: 0, relatively large, makes substantial contribution to the margin of the acetabulum; 1, reduced in size, rudimentary, nearly excluded from the acetabulum (Butler et al., 2008).

338. Openings in the body of the pubis (obturator foramen): 0, absent, no obturator process or notch; 1, one, single obturator foramen or obturator notch present; 2, two, distinct second opening in the main body ("ceratosaur" foramen). NEW, ORDERED

339. Combined transverse width of both pubes: 0, less than 75% of their length; 1, more than 75% of their length (Cooper, 1984; Ezcurra, 2010).
340. Pubis/femur length: 0, less than or equal to 0.5; 1, more than 0.5 but less than 0.7; 2, equal to or more than 0.7 (modified from Novas, 1996; Pol et al., 2011b).
341. Body of the pubis, dorsolaterally rotated so that obturator foramen is obscured in lateral view: 0, absent; 1, present (modified from Butler et al., 2008).
342. Prepubic process: 0, absent; 1, present (Sereno, 1986; Butler et al., 2008; Nesbitt, 2011).
343. Prepubic process: 0, compressed mediolaterally, dorsoventral height exceeds mediolateral width; 1, rod-like, mediolateral width exceeds dorsoventral height (Butler et al., 2008).
344. Prepubic process, length: 0, stub-like and poorly developed, extends only a short distance anterior to the pubic peduncle of the ilium; 1, elongated into distinct anterior process (Butler et al., 2008).
345. Extended prepubic process, extends beyond distal end of preacetabular process of ilium: 0, absent; 1, present (modified from Butler et al., 2008).
346. Extent of pubic symphysis: 0, elongate; 1, restricted to distal end of pubic blade, or absent (Butler et al., 2008).
347. Pubis, pubic apron: 0, present; 1, absent. NEW
348. Pubis, median gap below the pubic apron: 0, present; 1, absent, distal pubes swollen and contact along their medial surfaces. NEW
349. Pubis, anteroposterior expansion of the distal portion: 0, present; 1, absent. NEW
350. Pubis, level of anteroposterior expansion of the distal portion: 0, large, distal portion is expanded to over 2.0 times the width of the mid-shaft forming a distinct 'boot'; 1, reduced, distal portion is expanded up to 2.0 times the width of the mid-shaft (knob-like swelling). NEW



351. At least some fusion of the pelvic elements (ilium, ischium pubis fused at their points of contact): 0, absent; 1, present. NEW
352. Tibia (or fibula)-femur length: 0, femur longer or about the same length as the tibia; 1, tibia longer (modified from Gauthier, 1986; Sereno, 1991; Juul, 1994; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011).
353. Femur, proximal portion, anteromedial tuber: 0, absent; 1, small and rounded; 2, offset medially (or posteriorly) relative to the posteromedial tuber (Gauthier, 1986; Benton, 1999; Clark et al., 2000; Olsen et al., 2000; Benton and Walker, 2002; Sues et al., 2003; Clark et al., 2004; Nesbitt, 2011). ORDERED
354. Femur, proximal portion, posteromedial tuber: 0, present and small; 1, present and largest of the proximal tubera; 2, absent (Novas, 1996; Nesbitt, 2005a; Irmis et al., 2007; Nesbitt, 2011).
355. Femur, proximal portion, anterolateral tuber: 0, present as an expansion; 1, absent, the anterolateral face is flat (modified from Sereno and Arcucci, 1994; Irmis et al., 2007; Nesbitt, 2011).
356. Femur, medial articular surface of the head in dorsal view: 0, rounded; 1, flat/ straight (Nesbitt, 2011).
357. Femoral head, narrowness (maximum anteroposterior breadth of femoral head < 30% of transverse width of the proximal surface of the femur): 0, absent, maximum anteroposterior breadth of femoral head is greater than 30% of transverse width of the proximal surface of the femur; 1, present, maximum anteroposterior breadth of femoral head is less than 30% of mediolateral width of the proximal surface of the femur. NEW
358. Femur, ventral to the proximal head: 0, smooth transition from the femoral shaft to the head; 1, notch; 2, concave emargination (Sereno and Arcucci, 1994a; Novas, 1996; Nesbitt, 2011).
359. Femoral shape in medial/lateral view: 0, bowed anteriorly along length; 1, relatively straight (Butler et al., 2008).
360. Medial bowing of the femur: 0, present, strong sigmoidal profile in anterior/posterior view; 1, present, small medial bowing forming gentle continuous curve; 2, absent, femur is straight in anterior/posterior view (new). ORDERED

361. Cross section of the mid-shaft of the femur: 0, roughly circular or elliptical, with the long axis running anteroposteriorly; 1, elliptical, with the long axis oriented mediolaterally (modified from Wilson and Sereno, 1998; Ezcurra, 2010).

362. Femur, femoral head orientation (long axis of the femoral head angle with respect to the transverse axis through the femoral condyles: 0, anterior; 1, anteromedial; 2, medial (modified from Benton and Clark, 1988; Hutchinson, 2001b; Nesbitt, 2011).

363. Femur, femoral head in medial and lateral views: 0, rounded; 1, hook shaped (Sereno and Arcucci, 1994a; Irmis et al., 2007; Nesbitt, 2011).

364. Femur, dorsolateral margin of the proximal portion: 0, smooth; 1, dorsolateral trochanter (modified from Nesbitt, 2011).

365. Dorsolateral trochanter, form: 0, sharp ridge; 1, rounded ridge (modified from Nesbitt, 2011).

366. Dorsolateral trochanter, fusion to the anterior trochanter: 0, absent, anterior trochanter and dorsolateral trochanter are separated by a gap; 1, present. NEW

367. Femur, anterior trochanter (lesser trochanter, M. iliofemoralis cranialis insertion): 0, absent; 1, present (modified from Bakker and Galton, 1974; Gauthier, 1986; Novas, 1992; Juul, 1994; Novas, 1996; Benton, 1999; Langer and Benton, 2006; Nesbitt et al., 2009c; Nesbitt, 2011).

368. Femur, anterolateral side of the femoral head: 0, featureless; 1, ventral emargination present (Sereno and Arcucci, 1994a; Irmis et al., 2007; Nesbitt, 2011).

369. Femur, anterior trochanteric shelf proximal to the attachment site of the M. caudifemoralis (insertion site for the M. iliofemoralis externus): 0, present; 1, absent (modified from Gauthier, 1986; Rowe and Gauthier, 1990; Novas, 1992, 1996; Langer and Benton, 2006; Nesbitt, 2011).

370. Anterior trochanter (lesser trochanter), morphology: 0, a very small, round tubercle; 1, elongate ridge that is oriented proximodistally (finger-like or spike-like); 2, broadened, prominent, 'wing' or 'blade' shaped (modified from Bakker and Galton, 1974; Gauthier, 1986; Novas, 1992; Juul, 1994; Novas, 1996; Benton, 1999; Langer and Benton, 2006; Nesbitt et al., 2009c; Nesbitt, 2011).

371. Broadened (wing or blade shaped) anterior trochanter, broadness in comparison with the greater trochanter: 0, as broad as the greater trochanter; 1, greater trochanter is broader. NEW
372. Anterior trochanter, completely connected to the shaft of the femur: 0, present; 1, absent, anterior trochanter is separated from the shaft by a marked cleft (modified from Bakker and Galton, 1974; Gauthier, 1986; Novas, 1992; Juul, 1994; Novas, 1996; Benton, 1999; Langer and Benton, 2006; Nesbitt et al., 2009c).
373. Level of most proximal point of anterior trochanter (lesser trochanter) relative to level of proximal femoral head: 0, anterior trochanter is positioned distally on the shaft; 1, anterior trochanter positioned proximally, approaches level of proximal surface of femoral head (modified from Butler et al., 2008).
374. Position of the anterior trochanter (lesser trochanter) in anterior view: 0, near the centre of the anterior face of the femoral shaft; 1, close to the lateral margin of the femoral shaft (Yates, 2007; Ezcurra, 2010).
375. Femur, proximal surface: 0, rounded and smooth; 1, transverse groove present (modified from Ezcurra, 2006; Nesbitt, 2011).
376. Transverse groove on femur, form: 0, transverse groove is shallow, poorly developed and is straight; 1, transverse groove is deep and well developed and is straight; 2, transverse groove is deep and well developed and is curved (modified from Ezcurra, 2006; Nesbitt, 2011). ORDERED
377. Fourth trochanter of femur: 0, absent; 1, present (modified from Butler et al., 2008).
378. Fourth trochanter of femur, shape: 0, low, mound-like and rounded; 1, raised, prominent ridge (aliform); 2, raised and pendant or rod-like (modified from Butler et al., 2008; Nesbitt, 2011). ORDERED
379. Fourth trochanter, position: 0, located entirely on proximal half of femur; 1, positioned at midlength, or distal to midlength (Butler et al., 2008).
380. Fourth trochanter: 0, symmetrical, with distal and proximal margins forming similar low-angle slopes to the shaft; 1, asymmetrical (modified from Langer and Benton, 2006; Nesbitt, 2011).
381. Pendent fourth trochanter, lateral deflection in distal section: 0, absent; 1, present. NEW

382. Transverse expansion of distal femur, ratio of the transverse width of the distal femur to the anteroposterior depth of the medial condyle: 0, greater than 1.5; 1, less than 1.5. NEW
383. Femur, distal condyles of the femur divided posteriorly: 0, less than 1/4 the length of the shaft; 1, between 1/4 and 1/3 the length of the shaft (Nesbitt, 2011).
384. Femur, anterior surface of the distal portion: 0, smooth; 1, distinct scar orientated mediolaterally; 2, scar oriented proximodistally (modified from Nesbitt et al., 2009a; Nesbitt, 2011).
385. Femur, crista tibiofibularis (fibular condyle, tibiofibular crest): 0, smaller or equal in size to the medial condyle; 1, larger than the medial condyle (modified from Sereno and Arcucci, 1994a; Irmis et al., 2007; Butler et al., 2008; Nesbitt, 2011).
386. Lateral condyle of distal femur, position and size in ventral view: 0, positioned relatively laterally; 1, strongly inset medially (modified from Butler et al., 2008).
387. Tibia, proximal portion, cnemial crest: 0, absent; 1, present and anteriorly straight; 2, present and curved anterolaterally (Benton and Clark, 1988; Juul, 1994; Novas, 1996; Benton, 1999; Irmis et al., 2007; Nesbitt, 2011). ORDERED
388. Cnemial crest, anteroposterior length in proximal view: 0, between 0.25 and 0.4 times the anteroposterior width of the proximal tibia; 1, over 0.5 times the anteroposterior width of the proximal tibia. NEW
389. Tibia, proximal surface: 0, flat or convex; 1, concave, the posterior condyles of the tibia are separated from the cnemial crest by a concave surface (Nesbitt, 2011).
390. Tibia, lateral (fibular) condyle of the proximal portion: 0, offset anteriorly from the medial condyle; 1, level with the medial condyle at its posterior border (Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011).
391. Tibia, lateral margin of the lateral condyle of the proximal portion: 0, rounded; 1, squared off (Nesbitt, 2011).

392. Tibia, lateral side of the proximal portion: 0, smooth; 1, dorsoventrally oriented crest present (fibular crest) (Gauthier, 1986; Rauhut, 2003; Nesbitt, 2011).
393. Tibia, posterolateral flange (posterolateral process, descending process) of the distal portion: 0, absent; 1, present and contacts fibula; 2, present and extends well posterior to the fibula (modified from Novas, 1992; Juul, 1994; Benton, 1999; Langer and Benton, 2006; Irmis et al., 2007; Nesbitt, 2011). ORDERED
394. Tibia, posterolateral margin of the distal end: 0, straight or convex; 1, concave (Irmis et al., 2007; Nesbitt, 2011).
395. Mediocranial corner of distal tibia forms: 0, rounded, obtuse or near right angle, 1, sharp, acute angle (Langer, 2004; Pol et al., 2011b).
396. Tibia, posterior side of the distal portion: 0, smooth and featureless; 1, dorsoventrally oriented groove or gap (Nesbitt, 2011).
397. Notch in distal tibia (with respective bump in the proximal astragalus): 0, absent, 1, present (modified from Novas, 1996; Langer, 2004; Nesbitt, 2011; Pol et al., 2011b).
398. Lateral migration of the proximodistally oriented groove on the distal tibia: 0, absent; 1, present. NEW
399. Tibia, anterior diagonal tuberosity (anteromedial sheet of Galton, 2014) located proximomedial to the anterior ascending process: 0, absent; 1, present (Ezcurra and Brusatte, 2011).
400. Tibia, proximodistally oriented ridge on the posterior face of the distal end: 0, absent; 1, present. NEW
401. Maximum expansion of distal tibia relative to proximal: 0, distal tibia is considerably less expanded than proximal tibia; 1, maximum expansion of distal tibia is roughly equal to that of proximal tibia, or greater (new).
402. Transverse width of the distal tibia: 0, subequal to or less than the anteroposterior width (distal tibia is square/circular); 1, greater than the anteroposterior width (around 1.25 times or more) (modified from Gauthier, 1986; Ezcurra, 2010).

403. Distal articular surface of tibia, forms an oblique angle with the long axis of the tibia in anterior and posterior views: 0, absent, inner and outer malleoli are roughly level with one another distally, forming a near right angle between the articular surface the condyles form and the long axis; 1, present, outer malleolus extends further distally than the inner malleolus creating an oblique between the articular surface and the long axis; 2, present, inner malleolus extends further distally. NEW

404. Fibula, attachment site for the M. iliofibularis, form: 0, knob shaped, robust; 1, crest shaped, low (modified from Sereno, 1991; Nesbitt, 2011).

405. Fibula, attachment site for the M. iliofibularis, location: 0, near the proximal portion; 1, near the mid-point between the proximal and distal ends (modified from Sereno, 1991; Nesbitt, 2011).

406. Fibula, anterior edge of the proximal portion: 0, rounded; 1, tapers to a point and arched anteromedially (Nesbitt, 2011).

407. Fibula respect to tibia at the middle of their shafts: 0, wider than half the width of the tibia, 1, subequal or narrower than half the width of the tibia (Langer, 2004; Pol et al., 2011b).

408. Fibula, distal end is strongly reduced and splint-like: 0, absent; 1, present (Han et al., 2012).

409. Tibia, fibula and proximal tarsals, fused (or partly fused) as a tibiotarsus (tibiofibulatarsus): 0, absent; 1, present. NEW

410. Astragalus and calcaneum, relative sizes: 0, astragalus and calcaneum roughly equal in size; 1, calcaneum greatly reduced in comparison to astragalus (Sereno and Arcucci, 1994).

411. Dorsally facing horizontal shelf forming part of the fibular facet of the astragalus: 0, present, 1, absent with a largely vertical fibular facet (Sereno, 1999).

412. Fibular facet on the lateral margin of the proximal surface of the astragalus: 0, large; 1, reduced to small articulation (Butler et al., 2008).

413. Astragalus, dorsally expanded process on the posterolateral portion of the tibial facet: 0, absent or poorly expanded; 1, expanded into a distinct, raised process (posterior ascending process

of Sereno and Arcucci, 1994, pyramidal process of Nesbitt and Ezcurra, 2015) (modified from Sereno and Arcucci, 1994; Nesbitt, 2011).

414. Astragalus, anterior ascending flange (anterior process, ascending process): 0, absent; 1, present (modified from Gauthier, 1986; Novas, 1992, 1996; Benton, 1999; Rauhut, 2003; Nesbitt, 2011).

415. Anterior ascending flange of the astragalus: 0, less than or equal to the height of the dorsoventral extent of the posterior side of the astragalus; 1, greater in height than the dorsoventral height of the posterior side astragalus (modified from Gauthier, 1986; Novas, 1992, 1996; Benton, 1999; Rauhut, 2003; Nesbitt, 2011).

416. Astragalus, anterior hollow: 0, shallow depression; 1, reduced to a foramen (extensor canal) (Nesbitt, 2011).

417. Astragalus, proximal surface: 0, lacks a marked rimmed and elliptical fossa posterior to the anterior ascending process; 1, possesses a marked rimmed and elliptical fossa posterior to the anterior ascending process (Langer and Benton, 2006; Nesbitt, 2011).

418. Astragalus, posterior groove: 0, present; 1, absent (Sereno, 1991; Nesbitt et al., 2009c; Nesbitt, 2011).

419. Astragalus in distal view, symmetry: 0, astragalar body is fairly symmetric, medial and lateral margins are about equal in depth; 1, astragalar body is strongly asymmetric, medial margin is at least 1.4 times as deep as lateral margin. NEW

420. Distal articular surface of astragalus: 0, relatively flat or weakly convex; 1, extremely convex and 'roller shaped' (Smith and Pol, 2007; Ezcurra, 2010).

421. Astragalus-calcaneum, articulation: 0, free; 1, coossified (Sereno and Arcucci, 1994; Irmis et al., 2007; Nesbitt, 2011; Han et al., 2012).

422. Calcaneum, proximal surface: 0, facet for tibia absent; 1, well-developed facet for tibia present (Butler et al., 2008).

423. Calcaneum, calcaneal tuber: 0, present; 1, absent (Gauthier, 1986; Sereno, 1991; Juul, 1994; Benton, 1999; Nesbitt, 2011).

424. Calcaneum, shape: 0, proximodistally compressed with a short posterior projection and medial process; 1, transversely compressed, with the reduction of these projections (modified from Langer and Benton, 2006; Nesbitt, 2011).
425. Calcaneum, fossa on the lateral surface: 0, absent; 1, present (Yates, 2007; Ezcurra, 2010).
426. Distal tarsals: 0, ossified; 1, not ossified. NEW
427. Distal tarsal 4, posterior prong: 0, blunt; 1, pointed (Langer and Benton, 2006; Nesbitt, 2011).
428. Distal tarsal 4, medial side: 0, without a distinct medial process present in the anteroposterior middle of the element; 1, with a distinct medial process present in the anteroposterior middle of the element (Nesbitt, 2011).
429. Distal tarsal 4, proximal surface: 0, flat; 1, distinct, proximally raised region on the posterior portion (heel of Sereno and Arcucci, 1994, 1994) (Nesbitt, 2011).
430. Medial distal tarsal: 0, articulates distally with metatarsal 3 only; 1, articulates distally with metatarsals 2 and 3 (Butler et al., 2008).
431. Medial distal tarsal: 0, not enlarged; 1, enlarged. NEW
432. Metatarsal III: 0, roughly equal to or shorter than 50% of tibial length; 1, longer than 50% of tibial length (modified from Sereno, 1991; Juul, 1994; Benton, 1999; Nesbitt, 2011).
433. Longest metatarsal: 0, metatarsal III is the longest; 1, metatarsal IV is the longest. NEW
434. Metatarsals, midshaft diameters: 0, both I and V subequal or greater than II–IV in diameter; 1, only diameter of metatarsal I greater than or equal to diameter of metatarsals II–IV; 2, only diameter of metatarsal V greater than or subequal to the diameters of metatarsal II–IV; 3, both I and V have diameters less than metatarsals II–IV (modified from Sereno, 1991; Juul, 1994; Novas, 1996; Benton, 1999; Nesbitt, 2011).



435. Metatarsal I: 0, reaches the proximal surface of metatarsal II; 1, does not contact the ankle joint and attaches onto the medial side of metatarsal II (modified from Gauthier, 1986; Rauhut, 2003; Nesbitt, 2011).
436. Metatarsal I: 0, subequal or greater in length than metatarsal II; 1, significantly shorter in length than metatarsal II. NEW
437. Metatarsal II, proximal articular surface: 0, subrectangular; 1, hour-glass shaped (Sereno, 1991; Pol and Powell, 2007).
438. Fusion of distal tarsals to proximal ends of metatarsals: 0, absent; 1, present. NEW
439. Metatarsal IV, distal articulation surface: 0, broader than deep and nearly symmetrical; 1, deeper than broad (or as broad as it is deep) and asymmetrical (modified from Sereno, 1999; Langer and Benton, 2006; Nesbitt, 2011).
440. Metatarsal IV, proximal portion, possesses an elongated lateral expansion that overlaps the anterior surface of metatarsal V: 0, absent; 1, present (Sereno, 1999; Langer and Benton, 2006; Nesbitt, 2011).
441. Metatarsal V: 0, present; 1, absent. NEW
442. Metatarsal V, phalanges: 0, present and “fully” developed first phalanx; 1, present and “poorly” developed first phalanx; 2, without phalanges (modified from Gauthier, 1984; Parrish, 1993; Nesbitt, 2011). ORDERED
443. Metatarsal V shape: 0, proximal and distal ends subequal in breadth, 1, proximal end is wider than the distal end, metatarsal V is triangular or y-shaped, with wide proximal surface and pointed distal end (Galton and Upchurch, 2004; Pol et al., 2011b).
444. Metatarsal V, length: 0, longer than 50% of metatarsal III; 1, shorter than 50% of metatarsal III (modified from Butler et al., 2008).
445. Metatarsals fused or partly fused into tarsometatarsus: 0, absent; 1, present. NEW

446. Digit 1: 0, metatarsal I robust and well-developed, distal end of phalanx 1–1 projects beyond the distal end of metatarsal II; 1, metatarsal I reduced, end of phalanx 1–1 does not extend much beyond the end of metatarsal II if at all; 2, metatarsal I reduced to a vestigial splint or absent, does not bear digits (Butler et al., 2008). ORDERED
447. Non-terminal phalanges, shape: 0, elongate; 1, subquadrangular (Pol and Powell, 2007).
448. Pedal digit 4 phalangeal number: 0, five or more; 1, four or fewer (Butler et al., 2008).
449. Majority of pedal unguals, shape: 0, claw-like; 1, hoof-like (modified from Butler et al., 2008).
450. Shape of the ungual of pedal digit I: 0, shallow, pointed, with convex sides and a broad ventral surface; 1, deep, abruptly tapering, with flattened sides and a narrow ventral surface. (McPhee et al. 2015).
451. Unguals of digits II-IV: 0, deeper than broad, with curved ventral surfaces; 1, broader than deep, with flat plantar surfaces. NEW
452. Epaxial ossified tendons present along vertebral column: 0, absent; 1, present (Butler et al., 2008).
453. Ossified hypaxial tendons, present on caudal vertebrae: 0, absent; 1, present (Butler et al., 2008).
454. Parasagittal row of dermal osteoderms on the dorsum of the body: 0, absent; 1, present (Butler et al., 2008).
455. Lateral row of keeled dermal osteoderms on the dorsum of the body: 0, absent; 1, present (Butler et al., 2008).
456. U-shaped cervical/pectoral collars composed of contiguous keeled osteoderms: 0, absent; 1, present (Butler et al., 2008).
457. Singular and unbranched filamentous integumentary structures covering, or partially covering, the outer body: 0, absent; 1, present. NEW





0100??  
 ??????  
 Sacisaurus\_agudoensis\_0??0?0-  
 100002???1??  
 ?????????1?????????0--10011000????????????????????????101????????1100-101?11000-  
 10?20010?0?000??000110????????1  
 00111????1??0000000?10?0200?0000  
 211??1010100??0-??0?0010????0--????0110010100?101001011-000111000-  
 ?10001?01011000100?011??0?0  
 0000?  
 Pisanosaurus\_mertii  
 0??11????????????????????????????????????  
 ???010111?  
 ??0??0000200?????????11?0-000-  
 11????????211112??000??0????0??0001??1??01??001????????????????????????????  
 ???  
 ?????????????????1????2????????????0????????????????0?10?0020101?1??10?20?1111?  
 ???1?000?0000??0?0100?0101011001110101?1000011????????1????????1?????0??0  
 0????0000  
 Fruitadens\_haagarorum  
 0????11?????????1?11????????????????0?????210????????????????????????????????  
 ???0102?0????  
 ?????????????0010311111100-000-  
 0121201002011011??000??1??1?0000?????0??01?????0?3?1??121?1001?100???  
 ??????????????????????1?1111000??  
 ???100012010?0??101201010-  
 12011100002000?110?0??1111101111?110111?10111111????????????????????????  
 ???????0000  
 Manidens\_condorensis 0????????????????????????????????????0?0?0-  
 0?21002????????????????110??0202001?020011001111021??00??0?0??1?????1???  
 ?????????????????????????????????210011?1-  
 002101020?01?????1001101100?2120?1?201111??000??1?1????????????????0??0??  
 ??01??3?111?12??1????????????????????????????01011????????????????????????  
 ?????????????11121100?01?0?2111000?0?0?0?10?022??-  
 1??11?0101??01?0?????0??  
 ???  
 Abrictosaurus\_consors  
 0000??1000?110?011100000010?100??00211020??011?10100001????????  
 ???011010101?010?11?  
 0?0??0?0?000103011010?1100??0122201?0201111??000??00-  
 ?????????????????????????????0?????1??1????????????????0?001?????111?11??0001  
 ?????00??1100?001?0?001??011120100000201211101--  
 000?0????????????????????????????????????01?????0?0?????1?020111??1201????  
 ???0??1?????1111??1101?????????1??1?????????10?11????????01000001?00  
 00  
 Tianyulong\_confuciusi 000010110001?0?0111000000?0?1000-  
 ??111?2000011110?????00??0????????????????????2????????????????????  
 ?????????????????11??010??000011?010??00??00010401?210?0-  
 00??0121200?02001020??000????????????????????????????????????1????1??001010  
 ?10??????????11?????1?1??1????????????0??11??1??10000??11?0????????  
 ?????????????011010????-  
 ?0?111????????????????1??0??0????????????????????12011?0?0011??11?????  
 ?11?????111?????????11??10??0??101?1?0?????110?000110001  
 Heterodontosaurus\_tucki  
 000010110001101011100000010110111001110200001110010000100?0020001  
 0112001100010002001010001001110?0101100110000??00??0?01101010100101110  
 0010000002000003011210110011001212?11020011111100?001?10010000010-00-  
 001?211?030100012001?0??10?01010-1010011?1?1111?1111?001110-

100002110010010000001111011120100000201211101--00010010100210-  
1111100101??0100?11-??01?0??120?0??101100201110-  
12110?000021000110????1?1110111111??1?1?1?1?11?11100100110?010110????110  
0000100000

Eocursor\_parvus\_

0??  
??  
00001100020????????????10?0-0??0?1??20?0?20110????000?????????0?00000?0-00-  
00?????????2?????11?01?????????????????010111?????101101101001?????????????  
1??1?????????????1112?1000012012?110001000?00101002?1-  
20011?0101?20100?11-??0110001202010101100201010-  
120111100020?001201011??11110?100????????????????????????????????1????0?????????0?  
????1?0000

Laquintasaura\_venezuelae\_

0???101????????????????????????????????????1000-  
??10??2?????????????????????10?000??00?????0?????0?????11????000?????????????  
??0??000??10010000-  
11??20?0?10?10?????00?0????????????????????????????????11?????????????????????  
?????000?1????1??11?2????00?????  
?0??00?0?????0?1202?10??111?0?????01?0?????0??00?2?2??0??1?120101??1  
201?0??1?????2010110??11?????1?1?????????11?????????????????????????????  
0?????????

Lesothosaurus\_diagnosticus

00??10101?0011100-  
1000?0?10?1001?001011200001110010000100?000??0011?100210001000000111000  
?0??11000?01100100000?001??10?01000001100100010000021100200??0010?01100  
-000-1110200002011110110?0?001?00???000010-00-  
0???011??20111011101?01111?0?????01001101?1111111010001110-  
100??100??00?0100?0001?1?112010000110122010002000100101202011101110010  
1020100011-1-0110000202020100101201010-  
120110000020000120101100111??110010101110100?111?0?100100?1101101-  
??010?0?0100000

Scelidosaurus\_harrisonii\_

000?1??0100??????????0?0?0??01000-  
0??1101100?101?011?2?010?0010310010100100000000100110000????????????1????  
??01?10?????????1?????????????10111?1-0??100021??0110??1000-000-  
101020000201111??0?0??1????00?????0-  
?????????111?220??1????0??0?????011-0-  
??00011????1?1111001?10????????????????????????????????????111201100011011101  
0002001?0010100200-?011100101021100011-1-  
0?1000?00212010010120101??1201?0?00020?????2??110?112??11001?1?1??????0  
1??0??0?00101??002110000100101110

Emausaurus\_ernsti\_

00??1??00??0??100-?000000?0?1000-  
00010020??0111001010001??0000300010100?00?0?000?00110?????????????????  
??00?????????????1?0??00110100111?000021000200??0110101100-000-  
1100200012011000??000??10-  
00??0??03??????10??0??1?????????????  
??  
??  
?????????????11?0

Agilisaurus\_louderbacki

00011000000010100-1000000?011000-  
001110200001110010111100?000030001010??10?01000100?011?0??0??1?00?0????  
??0??0?0??1????010?001110010111?1-0??0000200010110101000-000-  
11122000020111011000?0?????11?????????????0?????????1201?10120?0?0?????0?1  
-0-?10001101??1000?1101000?0-  
100????????????????????????????????1112010100110121010002100?001012020111001100  
101020101011-1-  
0110??10?0??1011??20101??1201?100101?????20?01??01?110?100101011?????  
1????0??00003110?00021100000?0100000

Hexinlusaurus\_multidens

0?0?1??0????????????????????????????????11000-  
??11?0200001110010000100?0000?0001010??10?01000?00?1110?????????????????

????????????????0?????1?00??11????????????0????????10010000-  
11??2000?201101????000??0??01????????????0??????120????11??1?0?????0?1  
-0-  
?1??01?????1??0?0????????????????00??0??01?????????111201010012?12101  
01--100?0010122210110111001010?0111111-1-  
0110????0??????1??2010???1201????00????????????????0??1?????????  
1??????1?????????????1?1?00?0100000  
*Jeholosaurus\_shangyuanensis* 00?01011000010110-10000001011000-  
00010?200001101010000100?0010300010101-  
1000111010?11100?02??1000?01????000????????????011100011?01011101-  
0020?012000?00101011?11000-  
111?200002011?101100000?1??001000001??0110010211??300010121211001110011  
-??11?101????1111111?1?00??0-  
?????????????????????????11120101000201201101--  
100?0011120211120011001?????1??11-??011?001202020101101211110-  
1201110000211?1?201011001111011001010110010001?110???110031100000211010  
00001?0000  
*Dracoraptor\_hanigani*  
00??100011??1??1??100?00?10?000??11?0?12????1011?0----  
?00?1001300??0????????????????????????????1001????????????????????????  
????????????????????????????????030??0000-000-  
0???10?0000000????0?0??????1??1?0??1?1??0????????????????0?????010  
111????????????????????????????110-  
??0??????????00??1????????????????????????????????0102112??????2?010  
?0??0---  
?01010?200002?201011010?201011?1?0?????????????????????10110???????  
?????????0?????0????01002110?0?0??00000  
*Massospondylus\_carinatus* 0001010011200-010-1111111-11?000-  
01000021010011100----  
10100000010011000001000???111110001010?0100??1101?01010??1?1??2?00---  
01010110110?000001000200110211200000-000-  
002021001210100111010??11??01?00011100112??0?11?01?00001?0100?0??001?  
?10?0010110?011012111011001100-  
103?1100??000001111211?0010010001001?012101000?000?001?20????-  
???0?001010200---??0100??0??00010????????????1101-  
?0????0????1??10000?0?0000111?111????0??0?????00100?0010?1100?00000  
00000  
*Massospondylus\_kaalea* 0????10011100-?10-1111111-  
1??00??01000020?00111100----  
1??0000?0011?0?????????????1?1??????01?1?????1??1??110?????????00---  
01010110111?00001?000200?00210200000-000-  
??2021001100100?11010??  
??  
??  
??  
?????????  
*Leyesaurus\_marayensis* 00??0??011?010?10-  
111??1?11?00??0100?02??0111100----  
?0?0000?00?0100??01?00000111????????????????????????01?000?????00---  
000??010110?0?0011000?00?1021?200000-000-  
002021?0021010??110?0?0?1101??000021??01?20?0????????????????????1??0??  
?????????????1??1??  
?????????????????1??22?????????0????????????0????????????????????  
??0110?0????????010?110?0?  
??00?????

*Antetonitrus\_ingenipes*  
0??  
??





000??1101-  
?0000??0001?0?10?????10?0001??110????00????0110?00?10100??02110?000100  
0000  
Aardonyx\_celestae 00?101?010200-??0-1010101-1??0?0-0100002??0?????0----  
0??0000??00??1?0????????????00110????????????????????????????????00---  
010??110?10?0??0100??00??011??100??0?????1????0121010????0?0??1?0?0?  
?0001110112??0??1??1??0??1??0?0011??01??1?????????????1????????????1101  
1??2????????????01??12????????????????????????????????????122????????2?000?1  
0??2?0---000010?10?00201120??1011-000??1111-  
00000?????1??01??????????00????????????????????????????????0??1?0?????0??01?0  
0000?  
Pantyraco\_caducus 00??1?00??00-????101????-  
10?01????000?21000110100----  
00?0000??00010?0?????0?0???2101100110001?1011?001??0000??0??1????00---  
000??100?10?0??1-000020000021010000-000-  
??12200?0100?011??010??111102?01?0?1000-  
0110????????????????????010101?????????????0??1??01??1?????????????????  
????????????????10010??100100?200100?2000?00?2202?01-  
11????????????????????0????????01????????????????????11?1-  
??000200?0?1??01000000??0000????????????????????????01010001021100000100  
00000  
Thecodontosaurus\_antiquus  
0??  
????????????????????????0010?0?11001?1?10000000?????????1?0---  
000??110????????????????0011?????0000-  
010100??2000?210100??000??0?????0?0000?1000-  
?0?????????0??0?0?01??10101010????000001000?1?011110110010-0-??00?0001-  
001?010112111001?????????????????????????????????0?????????????????2?????????????00  
??0?10?00201020?????0?????????1101-  
1000010000011001000000?????0?00011??100?????????????????????0?????0??0100  
0000?  
Herrerasaurus\_ischigualastensis 000000000000??000-1110000?110010-  
00000020000110100----  
000?0000300010000000000000010010100101??11001?10100000000?0010????00---  
000??010010?010010000000000200100000-000-  
00001001000000011100010?11110?0000011011100??211010000000001010011100??  
?????00111?????1??1010110?011110?0000?101-  
101100010101211100000011000012101000100011012110210022010001010200---  
0000000101002000101101001-000101101-  
1010020010010001000000101000110010110100010?011000103010011011000000100  
00000  
Chindesaurus\_bryansmalli  
0??  
??  
??  
????????????????00??1??1??1????????????????????????????????????  
?????????????????1?????????????????0??0?1??1?????????????????????1????????  
?????100002000101101001-0000?1101-  
10?001001?01000110?010?????0?10?1?11??0????????????????????????????  
?????  
Staurikosaurus\_pricei  
0??  
??  
00?00010010?000????000000????????0000????????0001????00000????0?0??1??0?  
?0000??1??0??0010100000000100?00110?????????????1????????????????  
?????????????????????????????????101000?1?0?0012?0100010001111?1??21??1?00001  
0?02?0---0000001?000020001011?1001-0001?1101-

10?0?20010010001000000101000??0  
0?????

Sanjuansaurus\_gordilloi

0????????????????????????????????1?0?0000??  
??  
????????????????????????????0000-000-  
00??10??00000????000??11110100000?10111001?11101000?0000010100??0???  
?????1011100011????????????11110????????????????0????????????1????????????  
????0????????????????????????00?01010100---  
???000010000200010?????0?????101101-  
1010011010010001000000?10001?01111000?000????????????0????????????0  
0?????

Eodromaeus\_murphi

0?????0????0????????????????????0?0?01010?0?02?01????0?????1???100????  
?10????????01????????????????????????????01??11?000????????????00---  
00??01?0?0?0?????01200000201000000-  
00??0?1010000000000000?000?001111021010111010?10??01?01????01??00??10  
?0101??010011010?101??11?????1110-  
10000?100110?1000010112?01?????????1?????1?002????0?1????????????02?020  
10210---00001?1???0?200010????1?01-  
?00????????00002?11?????1???0?????1000101?1???0?0001????0????????????0??  
????0????000000

Coelophysys\_bauri00001000012210??11101101110??000-00100020101100100----  
1?101001300010100000001??01111111?1?011100????10111?????001??0?00---  
0000?001010?000020000100100201000000-000-  
001010000000001011000?111111021111111010?01?0011?0201101110?1010011?010  
111?100011?101111111111001?110-100001101-  
11110000101121011000001?00211201110120101001120021?-10101002020200---  
00101112000?20202011?11020101121?????100002111111101110110110111?0101  
010110111?010??10311?11002110100000000000  
'''Syntarsus''' kayentakatae'

00?01000012210??111011011100?001?11100020?011?0110----  
1?1?100030001010000000?????1111110?10??1100????????????????????????00---  
000??00101??000??1000200100200000000-000-  
001?10?00000001????000????????????1??1?1?1?1?0????????1????????????????  
?????000?1?1011????????????????????????0????????0????????11????????????  
????????????1????2????????2??2?????0?????????01112000021102011011020101121  
100-  
100002011011?1011000101011011??1?1?111?11?0??0??311?1?021?1?0?0?0?  
?000?

Eoraptor\_lunensis01001000100010?0101010000100?000-00100020101101100----  
1?10100030001011010000101101?11????????????0??1??1?010?0?0011????00---  
0001?0011101000020001200110200000000-000-  
00101000000010000000??111?11?00001101110010001011000?0010??010??010  
1??0010011?1?1101111111?001100-  
10000110001011010111113101000?001?001112?1110020101001220021?-  
2200?001010?00---00?1-01?00??020101001?020100??1101-  
100002?????0?01?????1??00011101?10?1000??1011?1?103110?1?02110?000000  
00000

Procompsognathus\_triassicus

00??1????????????????????????000010??100?20?0110?100----  
10??100?000??100?0??0????11110????????????????0??1????????????????0?????  
?1??0010??00?????00200?????0000-  
00??0??10?0?000000?110?0?????????2??1????????????1011????????????01??  
????????????????????????????????1110-  
?00????????????0??0??101?????1??1?2??1101??0????????????????????2?0?0  
20?00---000??1?????0?0??1001?0????????1100-

?????211???1???11??01????1?????1??????1?????0?????10311?1??02110?000000  
00000  
Tawa\_hallae 00?01000?0?210??1110?101110??000-01000?2????100100----  
??1?00013000?110?10000??????10?0000?0?110??0?000110000??????1?0100---  
00000001010?010????00000?00300000000-000-  
00?010?000000000??0?0?1111?10?1110011?????0?00??????00?00?0?????011????  
1????010111????1?11111110??11?0-  
00???21?0?1111000110?12101?????00?001112?11100?010?0?1????2?????????0?20  
?0?00---?0?00012000?20102010010?20001121100-  
1000020011010001000011001?00111011111000011101100010301??1002110?????0?  
0000?  
Euparkeria\_capensis 0000000000000-000-0-00100-000000-  
00000010000110000----  
000100000000100000000000001000010000100010010000?0000000?00000000000---  
000000000010000000000000000000200000000-000-0?0010010000000001000?0000-  
0000000000-00-00001??1100000000000?0??0-?000010000110-  
0000011011100?000????000??000??0?0?10?0?00?0000010000000000000001--  
00?00000000000-000000120?1?00---0001-000100?000?100--000-----0?1000-  
?00000-000000?00-??0?00001000?000-  
0?01?000??00000000000?00000100000000001?00  
Postosuchus\_kirkpatricki 0000000000020-010-0-10000-10?000-  
00200020001100000----  
0000300020000001011110000011100100111020??010010010?0000?000011??00---  
01000210010000?001000200000200000000-000-  
0000100000000000110100??0?00??000?100110010?01022?10000?00??00??0???  
????00000111?11000011100001110-  
100??000??0000000100010000101010000100010000001010000102100???1100?0021  
002?0---1000000100000000100--000-----0?1000-000000-000000110-  
??11001000000100-0?0?0000??0??000010100100?10010000000??0?  
Dilophosaurus\_wetherilli  
00101000111211?11110100110000001010100120101100110----  
101000013000111001010000001?110110010011?0011??10110?????????0?2?00---  
000000110101000??1?00200000200100000-000-  
001010100000001111010?0111110?1120011011100?00010?2?1000110010010100010  
1????0000110101111111010001110-  
100??212??0111000110112111100000100121221110120101011?11121??00?011020  
002?0---?0?01112000020101011010120?01121101-  
00?002011121?01110110101?00111011101??0?11?00100010211?11002??0100000  
00000  
Tazoudasaurus\_naimi  
0??  
?????0?????00????0?0???0---  
01010110?10?0????0000?0010??????00010000-  
00??21?0?210110????000?0????0?000?1??11????201????????????????1000??0??  
??  
????????????????1?????????????00?1?010100---  
001??0????????121?????1?????1?????????????1????????????????????1?00?11111?  
1?0?0?????????????????0?????0?0?11100????  
Yunnanosaurus\_huangi 00?101?001?01????0-  
1?01?1?0?000??1?0?02000?110?00----  
1??1?00?000??00010?000????10?100000??00001?????????????????????00---  
01??1?0?10?0?????????0??0????0000-000-  
0?2?2??0?2100001??0??1??1?010??000111?0112??0?01??10000010010100????01?  
??10000??????101011101?101100-  
??2??1?0??00?00101111?00100100?0?001012011000200000112200201-  
2??00001010200---0010100??00201010??1011-000??1101-  
1000020000011001000010101000111111?1?0000101?????????101100101110000000  
0000?



Sinosaurus\_triassicus

0010100011201??0111111011000000??00?0002??01100110----
0???0000100011110201100???011101??1?2?11000?0101110000?????????0?00---
0001000?010?000??0000200??0101000000-000-
0010100000000001??000???????1??11?????1??0??0??1?12?1??0?????0?0????01?
?1??1000110101111111?1?00111??1????????????????????????????11030001?012112
0011001010?001?20020?-1?10?00201020?????01-
???020?0??010???1?1??2010????1100-
0?1?021111???101?0?01?1000001???1?????1101110?????103?????0?0211?201?0?0
00000

Ignotosaurus\_fragilis

0??
??
??
??
????????????????????000100011101120000000201001????????????????????????????
??0??
??

Lophostropheus\_airelensis

0??
??
????????????????????????00????????????????10??00????????????????1??0??111111010?
????????2??1?010?0?1??1??
????????????????11?0?0?1??21?2?0110?2010?0????????????????????????????
??
??

Panguraptor\_lufengensis

00?01????????????11????????????0001010100?20??110?100----
??1?10013000?0100100001??????110????????????????????????????????????00---
00??001??0?00??1??20000?????000??0??0??01?00?000000??000??????1?2
1?1111??1??0??0?01?0????????????????????????????????10011????1????????????
????????11??0??0??111??1????????????????2??1?0??0?????02??????10?????
????????????1????2??0?0??1?0??00????????????2????1????11????????1
?01??????00??10??01?????1?00?1?0?0??0?000?

Sarcosaurus\_woodi

0??
??
??
??
????????????????110300010002012011101201010?1????????????02?0?00?00---
?????0????????010??11?1001-?00??1101-
??
??????

Pulanesaura\_eocollum

0??
??
??
????????????????????00010000-
00??21??21?10??????0??0100??00002?1001111??101????????????????101??00??
?10????????????????11??????1011??????0????????????????????????????????
?????????0??0122002?1-
????????????????????????0??100?001??0100
?000??01?00000?

Pampadromaeus\_barberenai

00?010001120?0?00-1??1011?1?0010-
1100002000?110100----
0?0?0000300010?0????000?????0??10????????????????????????????????00---
000?000010?0?0?0?00100100210100000-000-
0?1320000100100101010????????????????1??????0????????????????????????
????????0001?????1?????????1????????????????????????????????001?00000?10?2



**Dinosauria:** 18 (0->1), 83 (0->1), 93 (0->1), 189 (0->1), 194 (0->1), 253 (0->1), 272 (0->1), 301 (1->0), 306 (0->2), 361 (1->0), 380 (0->1), 387 (1->2), 411 (0->1), 415 (0->1), 423 (0->1)

**Ornithoscelida:** 12 (0->1), 35 (0->1), 54 (0->1), 76 (0->1), 88 (1->0), 90 (1->0), 97 (1->0), 100 (0->1), 145 (?->2), 222 (0->1), 228 (0->1), 241 (0->1), 256 (0->1), 308 (0->1), 360 (0->1), 370 (1->2), 372 (0->1), 412 (0->1), 424 (0->1), 435 (0->1), 438 (0->1)

**Saurischia:** 26 (0->1), 30 (0->1), 89 (1->0), 180 (0->1), 224 (0->1), 247 (1->0), 286 (0->1), 321 (0->2), 330 (0->2), 402 (1->0), 417 (0->1), 440 (0->1), 446 (1->0), 450 (0->1)

**Theropoda:** 8 (0->1), 41 (0->1), 43 (0->1), 45 (1->0), 56 (0->1), 103 (0->1), 131 (0->1), 135 (0->1), 279 (0->1), 285 (0->1), 289 (1->2), 304 (0->1), 310 (0->1), 315 (0->1), 322 (1->2)

**Ornithischia:** 36 (0->1), 37 (0->1), 134 (0->1), 156 (0->1), 166 (0->1), 174 (0->2), 176 (0->1), 374 (0->1), 407 (0->1)

**Sauropodomorpha:** 8 (0->1), 9 (0->1), 21 (0->1), 23 (0->1), 24 (0->1), 34 (0->1), 84 (0->1), 85 (1->0), 148 (0->1), 152 (0->1), 169 (1->2), 174 (0->1), 184 (0->1), 194 (1->2), 203 (1->0), 295 (0->1), 322 (1->2), 394 (0->1)

**Silesauridae:** 31 (0->1), 33 (0->1), 91 (0->1), 95 (0->1), 111 (0->1), 161 (0->1), 300 (0->1), 305 (1->2), 315 (0->1), 383 (0->1)

**Dinosauria+Saltopus:** 258 (0->1), 267 (0->1), 325 (1->2)

**Herrerasauridae:** 243 (0->1), 303 (1->0), 313 (2->1), 318 (0->1), 365 (0->1), 390 (0->1)

## References cited in Supplementary Information

- Alcober, O., and R. N. Martínez. 2010. A new herrerasaurid (Dinosauria, Saurischia) from the Upper Triassic Ischigualasto Formation of northwestern Argentina. *ZooKeys* 63: 55–81.
- Allain, R., N. Aquesbi, J. Dejax, C. Meyer, M. Monbaron, C. Montenat, P. Richir, M. Rochdy, D. Russell, and P. Taquet. 2004. A basal sauropod dinosaur from the Early Jurassic of Morocco. *C R Palevol* 3: 199–208.
- Apaldetti, C., R. N. Martinez, O. A. Alcober, and D. Pol. 2011. A New Basal Sauropodomorph (Dinosauria: Saurischia) from Quebrada del Barro Formation (Marayes-El Carrizal Basin), Northwestern Argentina. *PLoS ONE* 6(11): e26964.
- Apaldetti, C., D. Pol, and A. M. Yates. 2013. The postcranial anatomy of *Coloradisaurus brevis* (Dinosauria: Sauropodomorpha) from the Late Triassic of Argentina and its phylogenetic implications. *Palaeontology*, 56: 277–301.
- Apaldetti, C., R. N. Martinez, D. Pol, and T. Souter. 2014. Redescription of the Skull of *Coloradisaurus brevis* (Dinosauria, Sauropodomorpha) from the Late Triassic Los Colorados Formation of the Ischigualasto-Villa Union Basin, northwestern Argentina, *Journal of Vertebrate Paleontology*, 34:5, 1113–1132.
- Bakker, R. T., and P. M. Galton. 1974. Dinosaur monophyly and a new class of vertebrates. *Nature* 248: 168–172.
- Baron, M. G., D. B. Norman, and P.M. Barrett. 2016. Postcranial anatomy of *Lesothosaurus diagnosticus* (Dinosauria: Ornithischia) from the Lower Jurassic of southern Africa: implications for basal ornithischian taxonomy and systematics. *Zoological Journal of the Linnean Society*. 10.1111/zoj.12434
- Barrett, P. M. 2009. A new basal sauropodomorph dinosaur from the Upper Elliot Formation (Lower Jurassic) of South Africa. *Journal of Vertebrate Paleontology* 29: 1032–1045.
- Barrett, P. M., and A. M. Yates. 2006. New information on the palate and lower jaw of *Massospondylus* (Dinosauria: Sauropodomorpha). *Palaeontologia africana* 41: 123–130.
- Barrett, P. M., and F. -L. Han. 2009. Cranial anatomy of *Jeholosaurus shangyuanensis* (Dinosauria: Ornithischia) from the Early Cretaceous of China. *Zootaxa* 2072: 31–55.
- Barrett, P. M., R. J. Butler, and F. Knoll. 2005a. Small-Bodied Ornithischian Dinosaurs from the Middle Jurassic of Sichuan, China. *Journal of Vertebrate Paleontology* 25(4), 823–834.
- Barrett, P. M., P. Upchurch, and X. -L. Wang. 2005. Cranial Osteology of *Lufengosaurus huenei* Young (Dinosauria: Prosauropoda) from the Lower Jurassic of Yunnan, People's Republic of China. *Journal of Vertebrate Paleontology* 25(4), 806–822.
- Barrett, P. M., R. J. Butler, R. Mundil, T. M. Scheyer, R. B. Irmis, and M. R. Sánchez-Villagra. 2014. A palaeoequatorial ornithischian and new constraints on early dinosaur diversification. *Proceedings of the Royal Society B. Royal Society* 281: 20141147.
- Barrett, P. M., D. C. Evans, and N. E. Campione. 2015. Evolution of dinosaur epidermal structures. *Biology Letters* 11: 20150229.
- Bell, M. A., and G. T. Lloyd. 2015. strap: an R package for plotting phylogenies against stratigraphy and assessing their stratigraphic congruence. *Palaeontology* 58: 379–389.



- Bennett, S. C. 1996. The phylogenetic position of the Pterosauria within Archosauromorpha. *Zoological Journal of the Linnean Society* 118: 261–308.
- Benton, M. J. 1990. Origin and interrelationships of dinosaurs; pp. 11–30 in D.B. Weishampel, P. Dobson, and H. Osmólska (eds.), *The Dinosauria*. Berkeley: University of California Press.
- Benton, M. J. 1999. *Scleromochlus taylori* and the origin of dinosaurs and pterosaurs. *Philosophical Transactions of the Royal Society of London, Series B* 354: 1423–1446.
- Benton, M.J., and J.M. Clark. 1988. Archosaur phylogeny and the relationships of the Crocodylia. In M.J. Benton (editor), *The phylogeny and classification of the tetrapods*. Vol. 1. Amphibians and reptiles, 295–338. Oxford: Clarendon Press.
- Benton, M. J., and A. D. Walker. 2002. *Erpetosuchus*, a crocodile-like basal archosaur from the Late Triassic of Elgin, Scotland. *Biological Journal of the Linnean Society* 136: 25–47.
- Benton, M. J., and A. D. Walker. 2011. *Saltopus*, a dinosauriform from the Upper Triassic of Scotland, *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 101: 285–299.
- Benton, M. J., L. Juul, G. W. Storrs, and P. M. Galton. 2000. Anatomy and Systematics of the Prosauropod Dinosaur *Thecodontosaurus antiquus* from the Upper Triassic of Southwest England. *Journal of Vertebrate Paleontology*, 20(1): 77–108.
- Bittencourt J. S., A. B. Arcucci, C. A. Maricano, and M. C. Langer. 2015. Osteology of the Middle Triassic archosaur *Lewisuchus admixtus* Romer (Chañares Formation, Argentina) its inclusivity, and relationships amongst early dinosauromorphs. *Journal of Systematic Palaeontology* 13: 189–219.
- Bonaparte, J. F. 1976. *Pisanosaurus mertii* Casimiquela and the origin of the Ornithischia. *Journal of Paleontology* 50: 808–820.
- Bonaparte J. F., J. Ferigolo, and A. M. Ribeiro. 1999. A new early Late Triassic saurischian dinosaur from Rio Grande do Sol state, Brazil. *Proceedings of the Second Gondwanan Dinosaur Symposium, National Science Museum Monographs*. 15: 89–109.
- Brusatte, S. L., S. J. Nesbitt, R. B. Irmis, R. J. Butler, M. J. Benton, and M. A. Norell. 2010. The origin and early radiation of dinosaurs. *Earth-Science Reviews* 101(1), 68–100.
- Brusatte, S. L., G. Niedźwiedzki, and R. J. Butler. 2011. Footprints pull origin and diversification of dinosaur stem lineage deep into Early Triassic. *Proceedings of the Royal Society B* 278: 1107–1113.
- Butler, R. J. 2005. The ‘fabrosaurid’ ornithischian dinosaurs of the upper Elliot Formation (Lower Jurassic) of South Africa and Lesotho. *Zoological Journal of the Linnean Society* 145: 175–218.
- Butler R. J. 2010. The anatomy of the basal ornithischian dinosaur *Eocursor parvus* from the lower Elliot Formation (Late Triassic) of South Africa *Zoological Journal of the Linnean Society* 160: 648–684.
- Butler, R. J., R. M. H. Smith, and D. B. Norman. 2007. A primitive ornithischian dinosaur from the Late Triassic of South Africa, and the early evolution and diversification of Ornithischia. *Proceedings of the Royal Society of London, Series B* 274: 2041–2046.
- Butler, R. J., P. Upchurch, and D.B. Norman. 2008. The phylogeny of the ornithischian dinosaurs. *Journal of Systematic Palaeontology* 6: 1–40.

Butler, R. J., L. B. Porro, P. M. Galton, and L. M. Chiappe. 2012. Anatomy and Cranial Functional Morphology of the Small-Bodied Dinosaur *Fruitadens haagarorum* from the Upper Jurassic of the USA. *PLoS ONE* 7(4): e31556.

Cabreira, S. F., C. L. Schultz, J. S. Bittencourt, M. B. Soares, D. C. Fortier, L. R. Silva, and M. C. Langer. 2011. New stem-sauropodomorph (Dinosauria, Saurischia) from the Triassic of Brazil. *Naturwissenschaften* 98 (12): 1035–1040.

Carpenter, K. 1992. Tyrannosaurids (Dinosauria) of Asia and North America; pp. 250–268 in N. J. Mateer, and P. -J. Chen (eds.), *Aspects of nonmarine Cretaceous geology*. China Ocean Press, Beijing.

Chatterjee, S. 1985. *Postosuchus*, a new thecodontian reptile from the Triassic of Texas and the origin of tyrannosaurs. *Philosophical Transactions of the Royal Society of London, Series B* 309: 395–460.

Clark, J. M., X. Xu, C. A. Forster, and Y. Wang. 2004. A Middle Jurassic 'sphenosuchian' from China and the origin of the crocodylian skull. *Nature* 430: 1021–1024.

Cooper, M. R. 1984. Reassessment of *Vulcanodon karibaensis* Raath (Dinosauria: Saurischia) and the origin of Sauropoda. *Palaeontologia africana* 25: 203–231.

Dilkes, D. W. 1998. The Early Triassic rhynchosaur *Mesosuchus browni* and the interrelationships of basal archosauromorph reptiles. *Philosophical Transactions of the Royal Society of London Series B Biological Sciences* 353: 501–541.

Dzik, J. 2003. A beaked herbivorous archosaur with dinosaur affinities from the early Late Triassic of Poland. *Journal of Vertebrate Paleontology* 23: 556–574.

Ewer, R. F. 1965. The anatomy of the thecodont reptile *Euparkeria capensis* Broom. *Philosophical Transactions of the Royal Society of London, Series B* 248: 379–435.

Ezcurra, M. D. 2006. A review of the systematic position of the dinosauriform archosaur *Eucoelophysis baldwini* Sullivan and Lucas, 1999 from the Upper Triassic of New Mexico, USA. *Geodiversitas* 28: 649–684.

Ezcurra, M. D. 2007. The cranial anatomy of the coelophysoid theropod *Zupaysaurus rougieri* from the Upper Triassic of Argentina, *Historical Biology* 19: 185–202.

Ezcurra, M. D. 2010. A new early dinosaur (Saurischia: Sauropodomorpha) from the Late Triassic of Argentina: a reassessment of dinosaur origin and phylogeny. *Journal of Systematic Palaeontology* 8: 371–425.

Ezcurra, M. D., and G. Cuny. 2007. The coelophysoid *Lophostropheus airelensis*, gen. nov.: a review of the systematics of "*Liliensternus*" *airelensis* from the Triassic-Jurassic boundary outcrops of Normandy (France). *Journal of Vertebrate Paleontology* 27(1): 73–86.

Ezcurra, M. D., and F. E. Novas. 2007. Phylogenetic relationships of the Triassic theropod *Zupaysaurus rougieri* from NW Argentina, *Historical Biology* 19: 35–72.

Ezcurra, M. D., and S. L. Brusatte. 2011. Taxonomic and phylogenetic reassessment of the early neotheropod dinosaur *Camposaurus arizonensis* from the Late Triassic of North America *Palaeontology* 54: 763–772.

- Ferigolo, J., and M. C. Langer. 2007. A Late Triassic dinosauriform from south Brazil and the origin of the ornithischian predeontary bone. *Historical Biology* 19: 23–33.
- Fraser, N. C., K. Padian, G. M. Walkden, and A. L. M. Davis. 2002. Basal dinosauriform remains from Britain and the diagnosis of the Dinosauria. *Palaeontology* 45: 79–95.
- Galton, P. M. 1973. On the anatomy and relationships of *Efraasia diagnostica* (Huene) n.gen., a prosauropod dinosaur (Reptilia: Saurischia) from the Upper Triassic of Germany, *Paläontologische Zeitschrift* 47(3/4): 229–255.
- Galton, P. M. 1976. Prosauropod dinosaurs (Reptilia: Saurischia) of North America. *Postilla* 169: 1–98.
- Galton, P. M. 1977. On *Staurikosaurus pricei*, an early saurischian dinosaur from the Triassic of Brazil, with notes on the Herrerasauridae and Poposauridae. *Palaeontologische Zeitschrift* 51: 234–245.
- Galton, P. M. 1985. The poposaurid thecodontian *Teratosaurus suevicus* V. Meyer plus referred specimens mostly based on prosauropod dinosaurs from the Middle Stubensandstein Upper Triassic of Nordwürttemberg West Germany. *Stuttgarter Beiträge zur Naturkunde Serie B (Geologie und Palaeontologie)* 116: 1–29.
- Galton, P. M. 2014. Notes on the postcranial anatomy of the heterodontosaurid dinosaur *Heterodontosaurus tucki*, a basal ornithischian from the Lower Jurassic of South Africa. *Revue de Paleobiologie* 33(1): 97–141.
- Galton, P. M., and P. Upchurch. 2004. Prosauropoda; pp. 232–258 in D. B. Weishampel, P. Dodson, and H. Osmólska (eds.), *The Dinosauria*. 2nd edition. University of California Press, Berkeley.
- Gauthier, J. A. 1986. Saurischian monophyly and the origin of birds. *Memoirs of the California Academy of Science* 8: 1–55.
- Gauthier, J., and K. Padian. 1985. Phylogenetic, functional, and aerodynamic analyses of the origin of birds and their flight. In J. H. O. M. K. Hecht, G. Viohl, and P. Wellnhofer (eds.), *The Beginning of Birds*, 185–197. Eichstatt: Freunde des Jura Museums.
- Gauthier, J. A., A. G. Kluge, and T. Rowe. 1988. Amniote phylogeny and the importance of fossils. *Cladistics* 4: 105–209.
- Godefroit, P., S. M. Sinitsa, D. Dhouailly, Y. L. Bolotsky, A. V. Sizov, M. E. McNamara, M. J. Benton, and P. Spagna. 2014. A Jurassic ornithischian dinosaur from Siberia with both feathers and scales. *Science* 345: 451–455.
- Goloboff, P., J. Farris, and K. Nixon. 2008. TNT: a free program for phylogenetic analysis. *Cladistics* 24: 774–786.
- Gow, C. E. 1990. Morphology and growth of the *Massospondylus* braincase (Dinosauria, Prosauropoda). *Palaeontologia africana* 27, 59–75.
- Gower, D. J. 1999. The cranial and mandibular osteology of a new rauisuchian archosaur from the Middle Triassic of southern Germany. *Stuttgarter Beiträge zur Naturkunde Serie B (Geologie und Palaeontologie)* 280: 1–49.
- Gower, D. J. 2000. Rauisuchian archosaurs (Reptilia, Diapsida): an overview. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 218: 447–488.

- Gower, D. J. 2002. Braincase evolution in suchian archosaurs (Reptilia: Diapsida): evidence from the raiisuchian *Batrachotomus kupferzellensis*. *Zoological Journal of the Linnean Society* 136: 49–76.
- Gower, D. J., and A. G. Sennikov. 1996. Braincase morphology in early archosaurian reptiles. *Palaeontology* 39: 883–906.
- Gower, D. J., and E. Weber. 1998. The braincase of *Euparkeria*, and the evolutionary relationships of birds and crocodylians. *Biological Reviews* 73: 367–411.
- Han, F. -L., P. M. Barrett, R. J. Butler, and X. Xu. 2012. Postcranial anatomy of *Jeholosaurus shangyuanensis* (Dinosauria, Ornithischia) from the Lower Cretaceous Yixian Formation of China, *Journal of Vertebrate Paleontology* 32: 1370–1395.
- Haubold, H. 1990. Ein neuer Dinosaurier (Ornithischia, Thyreophora) aus dem Unteren Jura des nördlichen Mitteleuropa. *Revue de Paleobiologie* 9(1): 149–177.
- He X., C. Wang, S. Liu, F. Zhou, T. Lui, K. Cai, B. Dai. 1998. A new species of sauropod from the Early Jurassic of Gongxian Co., Sichuan. *Acta Geologica Sichuan* 18: 1–7.
- Holtz, T. R. J. 1994. The phylogenetic position of the Tyrannosauridae: implications for theropod systematics. *Journal of Paleontology* 68: 1100–1117.
- Hu, S. 1993. A Short Report on the Occurrence of *Dilophosaurus* from Jinning County, Yunnan Province. *Vertebrata Palasiatica* 31: 65–69.
- Hutchinson, J. R. 2001a. The evolution of femoral osteology and soft tissue on the line to extant birds (Neornithes). *Zoological Journal of the Linnean Society* 131: 169–197.
- Hutchinson, J. R. 2001b. The evolution of pelvic osteology and soft tissues on the line to extant birds. *Zoological Journal of the Linnean Society* 131: 123–168.
- Huxley, T. H. 1870. On the Classification of the Dinosauria with observations on the Dinosauria of the Trias. *Quarterly Journal of the Geological Society* 26: 32–51.
- Irmis, R. B., S. J. Nesbitt, K. Padian, N. D. Smith, A. H. Turner, D. Woody, and A. Downs. 2007. A Late Triassic dinosauriform assemblage from New Mexico and the rise of dinosaurs. *Science* 317: 358–361.
- Juul, L. 1994. The phylogeny of basal archosaurs. *Palaeontologia africana* 31: 1–38.
- Kammerer, C. F., S. J. Nesbitt, and N. H. Shubin. 2012. The first basal dinosauriform (Silesauridae) from the Late Triassic of Morocco. *Acta Palaeontologica Polonica* 57(2): 277–284.
- Langer, M. C. 2003. The pelvic and hindlimb anatomy of the stem-sauropod *Saturnalia tupiniquim*. *PaleoBios* 23: 1–40.
- Langer, M. C. 2004. Basal saurischians; pp. 25–46 in D. B., Weishampel, P. Dodson, and H. Osmólska (eds.), *The Dinosauria*, 2nd edition. Berkeley: University of California Press.
- Langer, M. C., and M. J. Benton. 2006. Early dinosaurs: a phylogenetic study. *Journal of Systematic Palaeontology* 4: 309–358.
- Langer, M. C., M. A. G. Franca, and S. Gabriel. 2007. The pectoral girdle and forelimb anatomy of the stem-sauropodomorph *Saturnalia tupiniquim* (Upper Triassic, Brazil). *Special Papers in Palaeontology* 77: 113–137.

- Leal, L. A., S. A. K. Azevedo, A. A. W. Kellner, and A. A. S. da Rosa. 2004. A new early dinosaur (Sauropodomorpha) from the Caturrita Formation (Late Triassic), Paraná Basin, Brazil. *Zootaxa* 690: 1–24.
- Makovicky, P. J., and H.-D. Sues. 1998. Anatomy and phylogenetic relationships of the theropod dinosaur *Microvenator celer* from the Lower Cretaceous of Montana. *American Museum Novitates* 3240: 1–27.
- Martill D. M., S. U. Vidovic, C. Howells, and J. R. Nudds. 2016. The Oldest Jurassic Dinosaur: A Basal Neotheropod from the Hettangian of Great Britain. *PLoS ONE* 11(1): e0145713.
- Martinez R. N., P. C. Sereno, O. A. Alcober, C. E. Colombi, P. R. Renne, I. P. Montañez, and B. S. Currie. 2011. A Basal Dinosaur from the Dawn of the Dinosaur Era in Southwestern Pangaea. *Science* 331 (6014): 206–210.
- Martínez, R. N., C. Apaldetti, O. A. Alcober, C. E. Colombi, P. C. Sereno, E. Fernandez, P. S. Malnis, G. A. Correa, and D. Abelin. 2013. Vertebrate succession in the Ischigualasto Formation. *Journal of Vertebrate Paleontology* 32: 10–30.
- Martínez R. N., C. Apaldetti, G. A. Correa, and D. Abelin. 2016. A Norian lagerpetid dinosauromorph from the Quebrada del Barro Formation, northwestern Argentina. *Ameghiniana* 53: 1–13.
- Martinez R. N., and O. A. Alcober. 2009. A Basal Sauropodomorph (Dinosauria: Saurischia) from the Ischigualasto Formation (Triassic, Carnian) and the Early Evolution of Sauropodomorpha. *PLoS ONE* 4(2): e4397.
- McPhee, B. W., A. M. Yates, J. N. Choiniere, and F. Abdala. 2014 The complete anatomy and phylogenetic relationships of *Antetonitrus ingenipes* (Sauropodiformes, Dinosauria): implications for the origins of Sauropoda. *Zoological Journal of the Linnean Society* 171, 151–205.
- McPhee, B.W., M. F. Bonnan, A. M. Yates, J. Neveling, and J. N. Choiniere. 2015. A new basal sauropod from the pre-Toarcian Jurassic of South Africa: evidence of niche-partitioning at the sauropodomorph–sauropod boundary? *Scientific Reports* 5: 13224.
- Nesbitt, S. J. 2007. The anatomy of *Effigia okeeffeae* (Archosauria, Suchia), theropod convergence, and the distribution of related taxa. *Bulletin of the American Museum of Natural History* 302: 1–84.
- Nesbitt S. J. 2011. The Early Evolution of Archosaurs: Relationships and the Origin of Major Clades. *Bulletin of the American Museum of Natural History* 352: 1–292.
- Nesbitt, S. J., and M. A. Norell. 2006. Extreme convergence in the body plans of an early suchian (Archosauria) and ornithomimid dinosaurs (Theropoda). *Proceedings of the Royal Society of London B Biological Sciences* 273: 1045–1048.
- Nesbitt, S. J., R. B. Irmis, and W. G. Parker. 2007. A critical re-evaluation of the Late Triassic dinosaur taxa of North America. *Journal of Systematic Palaeontology* 5: 209–243.
- Nesbitt, S.J., R. B. Irmis, W. G. Parker, N. D. Smith, A. H. Turner, and T. Rowe 2009a. Hindlimb osteology and distribution of basal dinosauromorphs from the Late Triassic of North America. *Journal of Vertebrate Paleontology* 29: 498–516.
- Nesbitt, S. J., N. D. Smith, R. B. Irmis, A. H. Turner, A. Downs, and M. A. Norell. 2009b. A complete skeleton of a Late Triassic saurischian and the early evolution of dinosaurs. *Science* 326: 1530–1533.

- Nesbitt, S. J., M. R. Stocker, B. Small, and A. Downs. 2009c. The osteology and relationships of *Vancleavea campi* (Reptilia: Archosauriformes). *Zoological Journal of the Linnean Society* 157: 814–864.
- Nesbitt, S. J., C. A. Sidor, R. B. Irmis, K. D. Angielczyk, R. M. H. Smith, and L. A. Tsuji. 2010. Ecologically distinct dinosaurian sister group shows early diversification of Ornithodira. *Nature* 464: 95–98.
- Nesbitt S. J., P. M. Barrett, S. Werning, C. A. Sidor, and A. J. Charig. 2013. The oldest dinosaur? A Middle Triassic dinosauriform from Tanzania. *Biology Letters* 9: 20120949.
- Norman, D. B., L. M. Witmer, and D. B. Weishampel Basal Ornithischia; pp. 325–334 in D. B. Weishampel, P. Dodson, and H. Osmólska H, (eds.), *The Dinosauria*. 2nd edition. Berkeley: University of California Press.
- Norman, D.B., A. W. Crompton, R. J. Butler, L. B. Porro, A. J. Charig. 2011. The Lower Jurassic ornithischian dinosaur *Heterodontosaurus tucki* Crompton and Charig, 1962: Cranial anatomy, functional morphology, taxonomy, and relationships. *Zoological Journal of the Linnean Society* 163: 182–276.
- Novas, F. E. 1992. Phylogenetic relationships of basal dinosaurs, the Herrerasauridae. *Palaeontology* 63: 51–62.
- Novas, F. E. 1994. New information on the systematics and postcranial skeleton of *Herrerasaurus ischigualastensis* (Theropoda: Herrerasauridae) from the Ischigualasto Formation (Upper Triassic) of Argentina. *Journal of Vertebrate Paleontology* 13: 400–423.
- Novas, F. E. 1996. Dinosaur monophyly. *Journal of Vertebrate Paleontology* 16: 723–741.
- Olsen, P. E., H. -D. Sues, and M. A. Norell. 2000. First record of *Erpetosuchus* (Reptilia: Archosauria) from the Late Triassic of North America. *Journal of Vertebrate Paleontology* 20: 633–636.
- Otero, A., E. Krupandan, D. Pol, A. Chinsamy, and J. N. Choiniere. 2015. A new basal sauropodiform from South Africa and the phylogenetic relationships of basal sauropodomorphs. *Zoological Journal of the Linnean Society* 174: 589–634.
- Padian, K. 2013. The problem of dinosaur origins: integrating three approaches to the rise of Dinosauria. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 103: 423–442.
- Parker, W. G. 2007. Reassessment of the Aetosaur '*Desmotosuchus chamaensis*' with a reanalysis of the phylogeny of the Aetosauria (Archosauria: Pseudosuchia). *Journal of Systematic Palaeontology* 5: 41–68.
- Parrish, J. M. 1993. Phylogeny of the Crocodylotarsi, with reference to archosaurian and crurotarsan monophyly. *Journal of Vertebrate Paleontology* 13: 287–308.
- Parrish, J. M. 1994. Cranial osteology of *Longosuchus meadei* and the phylogeny and distribution of the Aetosauria. *Journal of Vertebrate Paleontology* 14: 196–209.
- Peacock, B. R., C. A. Sidor, S. J. Nesbitt, R. M. H. Smith, J. S. Steyer, and K. D. Angielczyk. 2013. A new silesaurid from the upper Ntawere Formation of Zambia (Middle Triassic) demonstrates the rapid diversification of Silesauridae (Avemetatarsalia, Dinosauriformes). *Journal of Vertebrate Paleontology* 33(5): 1127–1137.

- Peng, G. 1992. Jurassic ornithopod *Agilisaurus louderbacki* (Ornithopoda: Fabrosauridae) from Zigong, Sichuan, China. *Vertebrata Palasiatica* 30: 39–51.
- Pol, D., and J. E. Powell. 2007. New information on *Lessemsaurus sauropoides* (Dinosauria: Sauropodomorpha) from the Upper Triassic of Argentina. *Special Papers in Palaeontology* 77: 223–243.
- Pol, D., O. W. M. Rauhut, and M. Becerra. 2011a. A Middle Jurassic heterodontosaurid dinosaur from Patagonia and the evolution of heterodontosaurids. *Naturwissenschaften* 98: 369–379.
- Pol D., A. Garrido, and I. A. Cerda. 2011b. A new sauropodomorph dinosaur from the Early Jurassic of Patagonia and the origin and evolution of the sauropod-type sacrum. *PLoS ONE* 6: e14572.
- Porro L.B., L. M. Witmer, and P. M. Barrett. 2015. Digital preparation and osteology of the skull of *Lesothosaurus diagnosticus* (Ornithischia: Dinosauria) *PeerJ* 3: e1494.
- Rauhut, O. W. M. 2003. The interrelationships and evolution of basal theropod dinosaurs. *Special Papers in Palaeontology* 69: 1–214.
- Rowe, T. 1989. A New Species of the Theropod Dinosaur *Syntarsus* from the Early Jurassic Kayenta Formation of Arizona *Journal of Vertebrate Paleontology* 9(2): 125–136.
- Rowe, T., and J. Gauthier. 1990. Ceratosauria; pp. 151–168 in D. B. Weishampel, P. Dodson, and H. Osmólska (eds.), *The Dinosauria*. Berkeley: University of California Press.
- Seeley, H. G. 1887. On the classification of the fossil animals commonly named Dinosauria. *Proceedings of the Royal Society of London*, 43: 165–171.
- Sereno, P. C. 1986. Phylogeny of the bird-hipped dinosaurs (Order Ornithischia). *National Geographic Society Research* 2: 234–256.
- Sereno, P. C. 1991. Basal archosaurs: phylogenetic relationships and functional implications. *Journal of Vertebrate Paleontology* 10(supplement to 3): 1–53.
- Sereno P. C. 1994. The Pectoral Girdle and Forelimb of the Basal Theropod *Herrerasaurus Ischigualastensis*. *Journal of Vertebrate Paleontology* 13(4): 425–450.
- Sereno, P. C. 1999. The evolution of dinosaurs. *Science* 284: 2137–2147.
- Sereno, P. C. 2005. The logical basis of phylogenetic taxonomy. *Systematic Biology* 54: 595–619.
- Sereno, P. C. 2012. Taxonomy, morphology, masticatory function and phylogeny of heterodontosaurid dinosaurs. *ZooKeys* 226: 1–225.
- Sereno, P. C., and R. Wild. 1992. *Procompsognathus*: theropod, “thecodont” or both? *Journal of Vertebrate Paleontology* 12: 435–458.
- Sereno, P. C., and A. B. Arcucci. 1994a. Dinosaurian precursors from the Middle Triassic of Argentina: *Lagerpeton chanarensis*. *Journal of Vertebrate Paleontology* 13: 385–399.
- Sereno, P. C., and A. B. Arcucci. 1994b. Dinosaurian precursors from the Middle Triassic of Argentina: *Marasuchus lilloensis*, gen. nov. *Journal of Vertebrate Paleontology* 14: 53–73.
- Sereno, P. C., and F. E. Novas. 1994. The skull and neck of the basal theropod *Herrerasaurus ischigualastensis*. *Journal of Vertebrate Paleontology* 13: 451–476.

- Sereno, P. C., C. A. Forster, R. R. Rogers, and A. M. Monetta. 1993. Primitive dinosaur skeleton from Argentina and the early evolution of Dinosauria. *Nature* 361: 64–66.
- Sereno, P. C., J. A. Wilson, H. C. E. Larsson, D. B. Dutheil, and H.-D. Sues. 1994. Early Cretaceous dinosaurs from the Sahara. *Science* 266: 267–270.
- Sereno, P. C., C. A. Forster, R. R. Rogers, and A. M. Monetta. 1996. Predatory dinosaurs from the Sahara and Late Cretaceous faunal differentiation. *Science* 272: 986–991.
- Sereno, P. C., R. N. Martínez, and O. A. Alcober. 2013. Osteology of *Eoraptor lunensis* (Dinosauria, Sauropodomorpha). Basal sauropodomorphs and the vertebrate fossil record of the Ischigualasto Formation (Late Triassic: Carnian-Norian) of Argentina. *Journal of Vertebrate Paleontology Memoir* 12: 83–179.
- Smith, N. D., and D. Pol. 2007. Anatomy of a basal sauropodomorph dinosaur from the Early Jurassic Hanson Formation of Antarctica. *Acta Palaeontologica Polonica* 52: 657–674.
- Smith, N. D., P. J. Makovicky, W. R. Hammer, and P. J. Currie. 2007. Osteology of *Cryolophosaurus ellioti* (Dinosauria: Theropoda) from the Early Jurassic of Antarctica and implications for early theropod evolution. *Zoological Journal of the Linnean Society* 151: 377–421.
- Sues, H. -D., P. E. Olsen, J. G. Carter, and D. M. Scott. 2003. A new crocodylomorph archosaur from the Upper Triassic of North Carolina. *Journal of Vertebrate Paleontology* 23: 329–343.
- Sullivan, R. M., and S. G. Lucas. 1999. *Eucoelophysis baldwini*, a new theropod dinosaur from the Upper Triassic of New Mexico, and the status of the original types of *Coelophysis*. *Journal of Vertebrate Paleontology* 19: 81–90.
- Taylor, M. P., P. Upchurch, A. M. Yates, M. J. Wedel, and D. Naish. 2010. Sauropoda. In De Queiroz, K., P.D. Cantino, J. A. Gauthier (eds.), *Phylonyms: a Companion to the PhyloCode*. University of California Press. Berkeley.
- Upchurch, P. 1995. The evolutionary history of sauropod dinosaurs. *Philosophical Transactions of the Royal Society of London B* 349, 365–390.
- Upchurch, P. 1998. The phylogenetic relationships of sauropod dinosaurs. *Zoological Journal of the Linnean Society* 124: 43–103.
- Weinbaum, J. C., and A. Hungerbühler. 2007. A revision of *Poqosaurus gracilis* (Archosauria: Suchia) based on two new specimens from the Late Triassic of the southwestern U.S.A. *Palaeontologische Zeitschrift* 81/2: 131–145.
- Weishampel, D. B., and L. M. Witmer. 1990. Heterodontosauridae; pp. 486–497 in D. B. Weishampel, P. Dodson, and H. Osmólska (eds.), *The Dinosauria*. Berkeley: University of California Press.
- Wilson, J. A., and P. C. Sereno. 1998. Early evolution and higher-level phylogeny of the sauropod dinosaurs. *Memoir of the Society of Vertebrate Paleontology* 5: 1–68.
- Xing, L., A. Paulina-Carabajal, P. J. Currie, X. Xu, J. Zhang, T. Wang, M. E. Burns, and Z. -M. Dong. 2014. Braincase Anatomy of the Basal Theropod *Sinosaurus* from the Early Jurassic of China. *Acta Geologica Sinica (English Edition)* 88: 1653–1664.



- Yates, A. M. 2003. A new species of the primitive dinosaur *Thecodontosaurus* (Saurischia: Sauropodomorpha) and its implications for the systematics of early dinosaurs. *Journal of Systematic Palaeontology* 1:1, 1-42.
- Yates, A. M. 2005. A new theropod dinosaur from the Early Jurassic of South Africa and its implications for the early evolution of theropods. *Palaeontologia africana* 41: 105–122.
- Yates, A. M. 2007. Solving a dinosaurian puzzle: the identity of *Aliwalia rex* Galton. *Historical Biology* 19: 93–123.
- Yates, A. M., and J. W. Kitching. 2003. The earliest known sauropod dinosaur and the first steps towards sauropod locomotion. *Proceedings of the Royal Society of London B* 270: 1753–1758.
- Yates, A.M., M. F. Bonnan, J. Neveling, A. Chinsamy, and M. G. Blackbeard. 2010. A new transitional sauropodomorph dinosaur from the Early Jurassic of South Africa and the evolution of sauropod feeding and quadrupedalism. *Proceedings of the Royal Society B* 277: 787–794.
- You, H. –L., Y. Azuma, T. Wang, Y. –M. Wang, and Z. –M. Dong. 2014. The first well-preserved coelophysoid theropod dinosaur from Asia. *Zootaxa* 3873(3): 233–249.
- Young, C. C. 1941. A complete osteology of *Lufengosaurus huenei* Young (gen. et sp. nov.). *Palaeontologica Sinica, Series C* 7: 1–53.
- Young, C. C. 1942. *Yunnanosaurus huangi* Young (gen. et sp. nov.), a new Prosauropoda from the Red Beds at Lufeng, Yunnan. *Bulletin of the Geological Society of China* 22: 63–104.
- Zheng, X. –T., H. –L. You, X. Xu, and Z. –M. Dong. 2009. An Early Cretaceous heterodontosaurid dinosaur with filamentous integumentary structures. *Nature* 458: 333–336.