www.sciencemag.org/cgi/content/full/321/5895/1485/DC1

Supporting Online Material for

Superiority, Competition, and Opportunism in the Evolutionary Radiation of Dinosaurs

Stephen L. Brusatte,* Michael J. Benton, Marcello Ruta, Graeme T. Lloyd

*To whom correspondence should be addressed. E-mail: brusatte@uchicago.edu

Published 12 September 2008, *Science* **321**, 1485 (2008)
DOI: 10.1126/science.1161833

This PDF file includes:

Materials and Methods

SOM Text

Figs. S1 to S4

Tables S1 to S29

References

1) Materials and Methods

The dataset includes 437 discrete skeletal characters scored across 64 Triassic archosaurs (see Supplementary Sections 8-9 below). Analyzed taxa include 3 outgroups (*Erythrosuchus*, *Euparkeria*, Proterochampsidae), 24 ornithodirans (1 basal ornithodiran, 4 pterosaurs, 8 non-dinosaurian dinosauromorphs, 11 dinosaurs), and 37 crurotarsans (4 phytosaurs, 4 aetosaurs, 2 ornithosuchids, 4 crocodylomorphs, 20 "rauisuchians," 3 Crurotarsi *incertae sedis*). Each major subgroup within Archosauria (e.g., Pterosauria, Ornithischia, Phytosauria) is represented by at least three exemplar taxa, which were selected to encompass the major body plans and morphological varieties. Further criteria in choosing exemplars included completeness of specimens and taxa that we were able to observe first-hand. Genera are used as proxies for species, as nearly all Triassic archosaur genera are monospecific. All taxa are Triassic except for the Early Jurassic *Heterodontosaurus*, which is used as a proxy for less complete heterodontosaurid fossils known from the Late Triassic (*S1*).

The character set is an assimilated list of discrete cladistic characters that includes all characters relevant to Triassic archosaur evolution (i.e., those characters that evolved in the Triassic) taken from the following sources: higher-level archosaur phylogeny (*S2*), Pterosauria (*S3* for autapomorphies; *S4* for ingroup characters), Phytosauria (*S3* for autapomorphies; *S5* for ingroup characters), Aetosauria (*S6* for autapomorphies and ingroup characters), Ornithosuchidae (*S3*), Crocodylomorpha (*S7* for autapomorphies and ingroup characters), Ornithischia (*S8* for autapomorphies and ingroup characters), Saurischia (*S9* for autapomorphies and ingroup characters, including those relevant to the sauropodomorph stem, Sauropoda, and Coelophysoidea). Ten characters are ordered and the rest unordered, and the ordered characters are not rescaled (*S10*). The matrix does not include autapomorphies of individual genera, as we utilize many exemplars and including autapomorphies may bias the dataset if certain exemplars have more autapomorphies than average for their subgroup or if they have been studied in greater detail (and hence more autapomorphies have been described). However, the dataset does include autapomorphies for terminal branches, as it includes characters that may define larger groups for which there is only one exemplar (thus, this analysis would optimize such a character as an autapomorphy of that exemplar).

The characters in this analysis have been derived from cladistic datasets, which may bias the disparity analyses towards recovering groups based on phylogeny rather than overall phenetic dissimilarity. However, this problem has been addressed by previous authors (e.g., *S11-14*), and the general consensus is that discrete cladistic characters are the best source of quantifying overall form for large and diverse groups such as archosaurs. Although possibly biased by phylogenetic signal and loss of information due to binning into discrete states, cladistic characters take into account a large range of information from across the skeleton that is difficult to extract with other methods (e.g., morphometrics). The use of cladistic characters is also ideal for the present study, as a large amount of systematic work has focused on archosaurs (especially dinosaurs), producing a ready source of data that otherwise would take much effort and time to collect from scratch.

For both disparity and evolutionary rates analysis (see below) taxa are binned according to clade and age. This is straightforward for clades, as the higher-level phylogenetic placement of the analyzed taxa in coarse bins (e.g., Dinosauria vs. Crurotarsi) is non-controversial (*S2*, *S15-16*). Taxa were binned into four stage-level intervals of the Middle-Late Triassic: Anisian, Ladinian, Carnian, and Norian.

Rhaetian taxa were not analyzed separately, but instead were binned with Norian taxa due to the short temporal range of the Rhaetian. These intervals "represent a compromise between resolution and sample size…(and are) sufficiently coarse that nearly all generic first and last occurrences can be unambiguously assigned" (*S11*). Taxon ranges were taken from the primary literature, as well as from several compilations (*S17-19*). As nearly all taxa are point occurrences, and none is known from two non-contiguous intervals, the "range through" method of sampling (*S12*) is not necessary. If the finest range resolution was, for instance, "Carnian-Norian," then the taxon was put into both bins. Individual genera were binned based on their observed fossil record with one exception: the Norian basal sauropodomorph *Pantydraco* was also placed in the Carnian bin to compensate for the very similar but substantially less complete Carnian taxon *Saturnalia*, which importantly extends the sauropodomorph lineage and body plan into the Carnian (the same time that the other two major dinosaur lineages, Theropoda and Ornithischia, originated). Absolute ages are only necessary for one evolutionary rate metric (see below).

The dataset may be biased if certain taxon or age bins are characterized by differential preservation rates. Preservation rates for major clades (Dinosauria, Crurotarsi) should theoretically be approximately equal, as both were inhabiting similar environments, both are characterized by similar body plans (and thus likely similar ecology), and in many cases members of the two clades lived side by side. It is difficult to address preservation rates by Triassic stage, but future analyses of available rock record (e.g., *S20*) may help rectify this. At the present time, there is no a priori reason to suspect differing preservation rates during the stages of the Triassic.

Finally, several of our comparisons are between dinosaurs and crurotarsans. These comparisons were chosen to address the question at hand: the early evolution of dinosaurs and the pattern of dinosaur macroevolution compared to that of their most important "competitors" (the crurotarsans). The identity of crurotarsans as the major "competitors" to dinosaurs is based on several lines of evidence: both are major clades of approximately the same taxonomic rank, both are heavily convergent on each other and possess a similar array of body plans (which is a strong indicator of general ecological crossover), and both lived alongside each other for 30 million years. Dinosaurs and crurotarsans are not sister taxa, but this is irrelevant to the question at hand. Analyzing the sister taxa Crurotarsi and Ornithodira would necessitate grouping with dinosaurs the morphologically bizarre pterosaurs and several fragmentary non-dinosaurian dinosauromorphs, neither of which have traditionally been included in discussions of dinosaur origins, and neither of which were likely ecologically overlapping with crurotarsans (with the possible exception of some dinosauromorphs). Since dinosaurs and crurotarsans are not sister taxa this means that they did not diverge at the same time, and that one group (crurotarans in this case) had a longer period of time over which to accumulate characters and body plans. However, this bias is addressed in the present study by the binning of data by Triassic stage and by the comparison of dinosaurs and crurotarsans that lived at the same time (Carnian and Norian).

However, as sister-taxon comparisons have a long history in evolutionary biology studies, and in this case can contribute additional information relevant to the macroevolution of major archosaur clades in the Triassic, we also provide analyses of evolutionary rates and disparity that compare Ornithodira (dinosaurs, pterosaurs, dinosauromorphs) with its sister taxon, Crurotarsi (see Tables S28-29).

A: Evolutionary Rates Analysis

The dataset was used to calculate evolutionary rates, which in this case refer to rates of morphological character change across the tree. A single tree was used to calculate rates, and was derived from a higher-level cladistic analysis of Archosauria (*S2*; the first 187 characters in the present dataset). The current dataset was not used to derive a phylogeny, as our character scoring strategy was to represent overall morphological similarity instead of phylogenetic relatedness. However, all of the taxa in the current study did not appear in the higher-level analysis, although exemplars of each major subgroup were present in the phylogenetic study. Thus, the first most parsimonious tree from the higher-level analysis was selected, and the ingroup relationships of Phytosauria, Aetosauria, Crocodylomorpha, Pterosauria, Ornithischia, and Saurischia were "grafted" onto the higher-level tree by reference to a parsimony analysis of the full 437 character dataset of the current study. Following S14 and S21, two rate metrics were calculated: 1) the patristic dissimilarity of each branch and 2) patristic dissimilarity of each branch divided by estimated temporal duration of that branch. Patristic dissimilarity of a branch is equivalent to branch length divided by number of comparable characters between taxa on the ends of each branch (either a terminal and a reconstructed ancestor or two reconstructed ancestors). Both ACCTRAN and DELTRAN optimizations were used to calculate branch length. The temporal duration of the branch was estimated following Ruta *et al*. (2006:2108-2109) with one exception. In those cases when the phylogeny does not imply a minimum divergence time (because a taxon appears in an older interval than its closest relative or several branches stem from the same point in time) we divided branch lengths equally among the branches in question, as opposed to the weighing scheme of Ruta *et al*. (2006) that divided lengths in proportion to the number of characters accumulated. Branches were binned according to age and clade, with age binning following the procedure of Ruta *et al*. (2006), which assigns branches to the latest possible temporal unit (for observed taxa the first occurrence, for reconstructed ancestors the unit in which the first sampled descendant appears). Statistical significance was assessed with the Mann-Whitney U test, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Unlike disparity analysis, calculation of evolutionary rates depends explicitly on a specific phylogenetic hypothesis (*S14*). This may be problematic if the phylogeny is poorly known or poorly supported, two criticisms that have been leveled at higher-level analyses of archosaur phylogeny (*S22*). However, this study utilizes a tree based on a new cladistic analysis of archosaurs (*S2*), which is the largest and most complete such study ever attempted, which more than doubles taxon and character sampling relative to the largest prior studies and produces a well-resolved phylogeny.

One evolutionary rate metric (patristic dissimilarity per branch) does not take into account absolute ages of taxa, only character data. However, the second metric (dissimilarity/time duration of branch) does factor in the absolute ages of taxa. This is problematic for the Triassic, as very few radiometric dates are available to calibrate the time scale (*S23-24*). We used the timescale of Gradstein et al. (2004) as a template, but modified it to include the recent suggestion of a much longer Norian and shorter Carnian (*S24*). Taxa were first binned as precisely as possible, down to a resolution of early, middle, or late in each stage, based on the primary literature (see above). In all cases taxa were given the absolute age of the midpoint of their most precise time bin (i.e., if the best resolution is "Carnian" then the taxon was given an age at the midpoint of the Carnian, if the best resolution is "early Norian" then the taxon was given an age at the midpoint of the early Norian). Because the Triassic time scale is poorly constrained the dissimilarity/time metrics should not be considered as absolute rates of evolution, but rather as relative rates to be compared among different groupings of Triassic archosaurs. As all taxa in the analysis are subjected to the same bias, treating these rates as relative circumvents the shortcomings of the current Triassic time scale.

B: Disparity Analysis

The dataset was used to derive a Euclidean distance matrix, which was then subjected to principal coordinates analysis. The PCO analysis ordinated taxa into a taxon-defined empirical morphospace, which is represented by a two dimensional plot of the first two axes in Figure 1. PCO combines information from the character matrix (437 characters) into a smaller and more manageable number of variables (63 axes), with the first axis representing those characters that contribute most to overall disparity, and each additional axis representing characters of successively less significance. Principal coordinates, as opposed to principal components, is well-suited to disparity analyses because it can better handle missing data and inapplicable characters, which are rife in the present dataset (*S10*, *S25-27*). Disparity metrics were calculated using the first 12 PCO axes, which encompass 63% of the cumulative variance, based on reference to significant changes in the scree plot. Four disparity metrics were calculated: the sum and product of the ranges and variances on the 12 axes (*S25*). Variance measures denote average dissimilarity among forms and are sensitive to taxonomic practice but robustly insensitive to sample size, whereas range measures indicate the entire spread of morphological variation ("absolute extent of bodyplan variety": *S28*) and are more sensitive to sampling biases. Both give an indication of volume of morphospace occupied. These measures were calculated using the software program Rare (*S28*). Multiplicative measures were normalized by taking the 12^{th} root. Taxa were binned according to age and clade. Statistical significance was assessed with non parametric multivariate analysis of variance (NPMANOVA), which tests for significant differences in the distribution of groups in morphospace. NPMANOVA evaluates similar distributions of variances in two or more groups of multivariate data (in our case, scores in the distance matrix) and operates through permutations of groups' elements (taxa) (*S29*). Bonferroni corrections were applied for multiple comparisons. Additional statistical information is given by the overlap or non-overlap of 95% bootstrap confidence intervals, which are calculated by Rare (1000 replications). This is a conservative test—it treats the data as two one-sample problems instead of a single two-sample problem—which we prefer, as it gives stronger confidence to a significant result. Rarefaction curves, also calculated by Rare, give an indication of sample-size biases, which are especially important to consider for range-based metrics.

2) Supplementary Text

A: Evolutionary Rates

Further results of the evolutionary rates analysis are presented in Supplementary Figure S2 and Supplementary Tables S1-S8. Additionlly, we present the following more detailed rates analyses:

i) Evolutionary Rates Analysis Results with Binned Characters

We binned the character list into three separate partitions: cranial (214 characters), axial (34 characters), and appendicular (169) characters. All other characters, which relate to dermal elements (osteoderms) were not included, since only crurotarsans possess these structures. To save space, we only report results obtained from ACCTRAN optimizations; DELTRAN optimizations gave nearly identical statistical results for all analyses.

As for the entire character list, there are no significant differences in evolutionary rates between all Triassic dinosaurs and crurotarsans when analyzing cranial and axial characters (Table S9). However, dinosaurs do exhibit a significantly higher rate of character evolution of the appendicular skeleton (Table S9). This suggests that the overall pattern of statistically indistinguishable rates between the two clades is largely driven by the statistically indistinguishable pattern of the skull (the largest character partition), which along with the axial characters swamps the statistically significant differences in appendicular character evolution. However, within Dinosauria there is no significant difference between the rate of evolution of cranial characters and appendicular characters, and furthermore there are no significant differences between the rates of any character partitions (Tables S16-S17). Thus, there is no evidence that a certain broad region of the dinosaur skeleton was evolving more rapidly during the Triassic.

Raw patristic dissimilarity measures for all crown group archosaurs show no significant changes across the Triassic (Tables S10-S15). However, the second metric (dissimilarity/time) shows evidence for decreasing rates across the Triassic with all three character partitions (Tables S10-S15), the same pattern seen when the entire dataset is analyzed. Therefore, the pattern of decreasing evolutionary rates within Archosauria, from an Anisian high to a Norian low, is not due to the excessive influence of one character partition. Instead, all three partitions contribute to the overall pattern.

ii) Evolutionary Rates Analysis Results: Synapomorphy and Homoplasy

Evolutionary rates analysis treats all changes as equal; that is, the acquisition of an unambiguous synapomorphy, a reversal, and the acquisition of a homoplastic synapomorphy are all treated as one character change. However, it may be informative to determine how much character change is due to the acquisition of novel synapomorphies versus oscillation between character states (homoplasy). We ran two restricted analyses, in which we binned data by clade (Crurotarsi vs. Dinosauria) and time (all archosaurs for each of the four intervals of the Triassic). Within each bin we counted the number of times each character state is acquired, based on a DELTRAN optimization. Previous studies (e.g., *S30*) have instead counted the number of changes for each character, but this is inappropriate for our dataset, which includes a number of multistate characters. If counting character changes, a six-state character that changed five times (i.e., each derived state is evolved once) would appear to be much more homoplastic than a binary character that changes once, even though in both cases each derived state is acquired one time. Thus, changes per character state instead of per character is the more appropriate and easily interpretable measure. Under these guidelines, if a character state changes once there is no homoplasy; if it changes more than once (two, three, etc. times) then it is homoplastic. The mean and median numbers of changes per character state were calculated for each taxonomic and time bin. Values closer to one imply less homoplasy, whereas larger values indicate greater homoplasy.

Crurotarsan character evolution is significantly more homoplastic than dinosaur evolution (Table S18). Or, in other words, dinosaur evolution is characterized by a significantly higher acquisition of novel synapomorphies, whereas crurotarsan evolution shows higher oscillation between character states. However, a much greater number of character states are relevant to crurotarsans (443 states) than dinosaurs (251 states), and crurotarsans have a longer duration than dinosaurs. Thus, the differences may largely be explained by the concept of character exhaustion (*S31*).

Homoplasy is significantly higher in the Carnian than during any other time interval (Table S19-20). Homoplasy is lowest, and thus novel state evolution is highest, in the Ladinian, but this is not significantly different from the Ladinian and Norian values.

B: Disparity

Further results of the evolutionary rates analysis are presented in Supplementary Figure S3-4 and Supplementary Tables S21-S27.

C: Rates and Disparity: Ornithodira vs. Crurotarsi

Comparing macroevolutionary patterns in sister taxa is a long-standing technique. Although comparing the evolutionary rates and disparity of Ornithodira and Crurotarsi doesn't directly address the question of how dinosaurs *sensu stricto* compared to their most likely "competitors," it can be illuminating. Ornithodira and Crurotarsi are the two major divisons of Crown Group Archosauria, and as sister taxa both diverged at the same time. Dinosaurs and crurotarsans were heavily convergent on each other and likely occupied similar niches, but Ornithodira includes one major body type and ecological niche that is unknown within Crurotarsi: flight (pterosaurs). Additionally, some non-dinosaurian dinosauromorphs (e.g., *Marasuchus*, *Lagerpeton*) seem to have occupied a distinct niche (small, slender saltator) and some dinosauromorphs (e.g., *Silesaurus*, *Sacisaurus*) were herbivores very similar in dental morphology to several crurotarsans and dinosaurs. It is also possible that non-dinosaurian ornithodirans possessed biological or anatomical features long postulated as "key characters" of dinosaurs, such as endothermic metabolism and more efficient breathing and locomotory strategies. Thus, comparing the entire array of ornithodirans with crurotarsans also sheds light on the early history of dinosaurs.

Comparison of evolutionary rates and disparity between these major clades returns near identical results to comparisons between crurotarsans and dinosaurs. Namely, crurotarsans are more disparate than ornithodirans with all four metrics, and these results are significant based on NPMANOVA tests and the non-overlap of error bars (with the exception of sum of variances, which is marginally significant; Table S28). Evolutionary rates of ornithodirans as a whole are slightly less than those of dinosaurs, but show non-significant differences when compared to those of crurotarsans (with the exception of one metric, which is also significant when dinosaurs and crurotarsans are compared; Table S29).

These results are intriguing. Even when the morphologically bizarre and ecologically distinctive pterosaurs are included in the analysis, not to mention non-dinosaurian dinosauromorphs that show their own unique body plans, the disparity of crurotarsans is still significantly greater than those of ornithodirans. Furthermore, evolutionary rates still show no overall pattern of significant difference. As

Ornithodira and Crurotarsi are sister taxa, this result cannot be explained by longer lineage durations or earlier origination. The pattern of higher disparity and larger morphospace exploration in crurotarsans appears robust.

3) Supplementary Figures

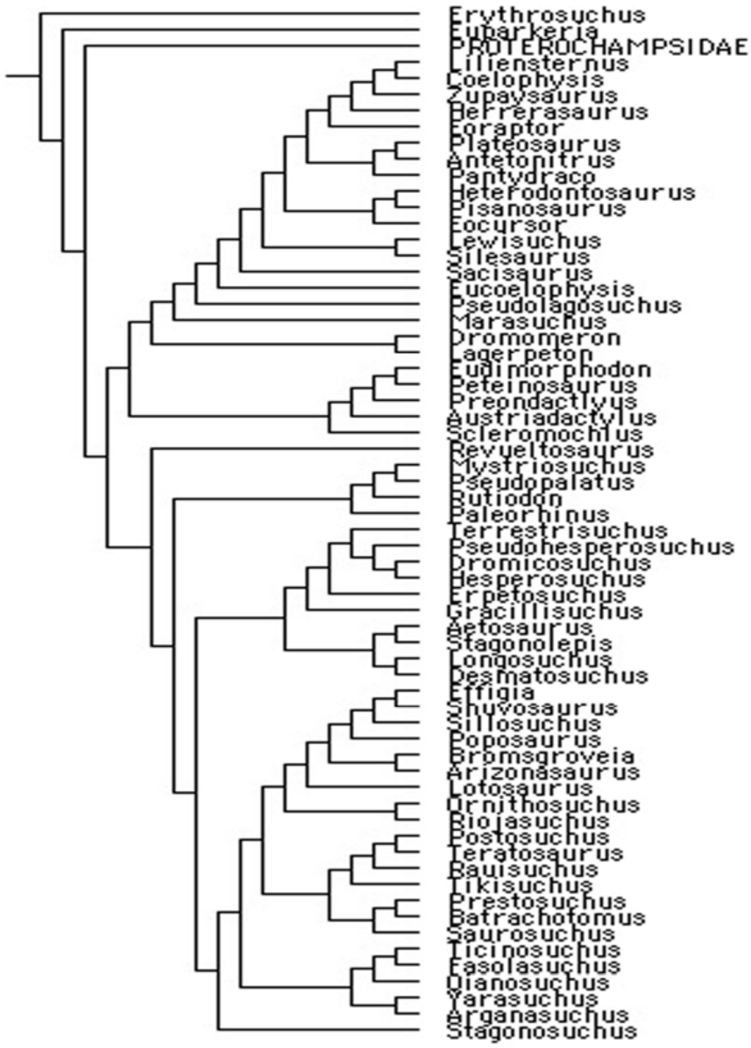

Fig. S1. Single tree used for evolutionary rates analysis. This tree was derived from a phylogenetic analysis, as detailed above. Outgroup taxa (*Erythrosuchus*, *Euparkeria*, Proterochampsidae) did not factor into any of the evolutionary rates analyses.

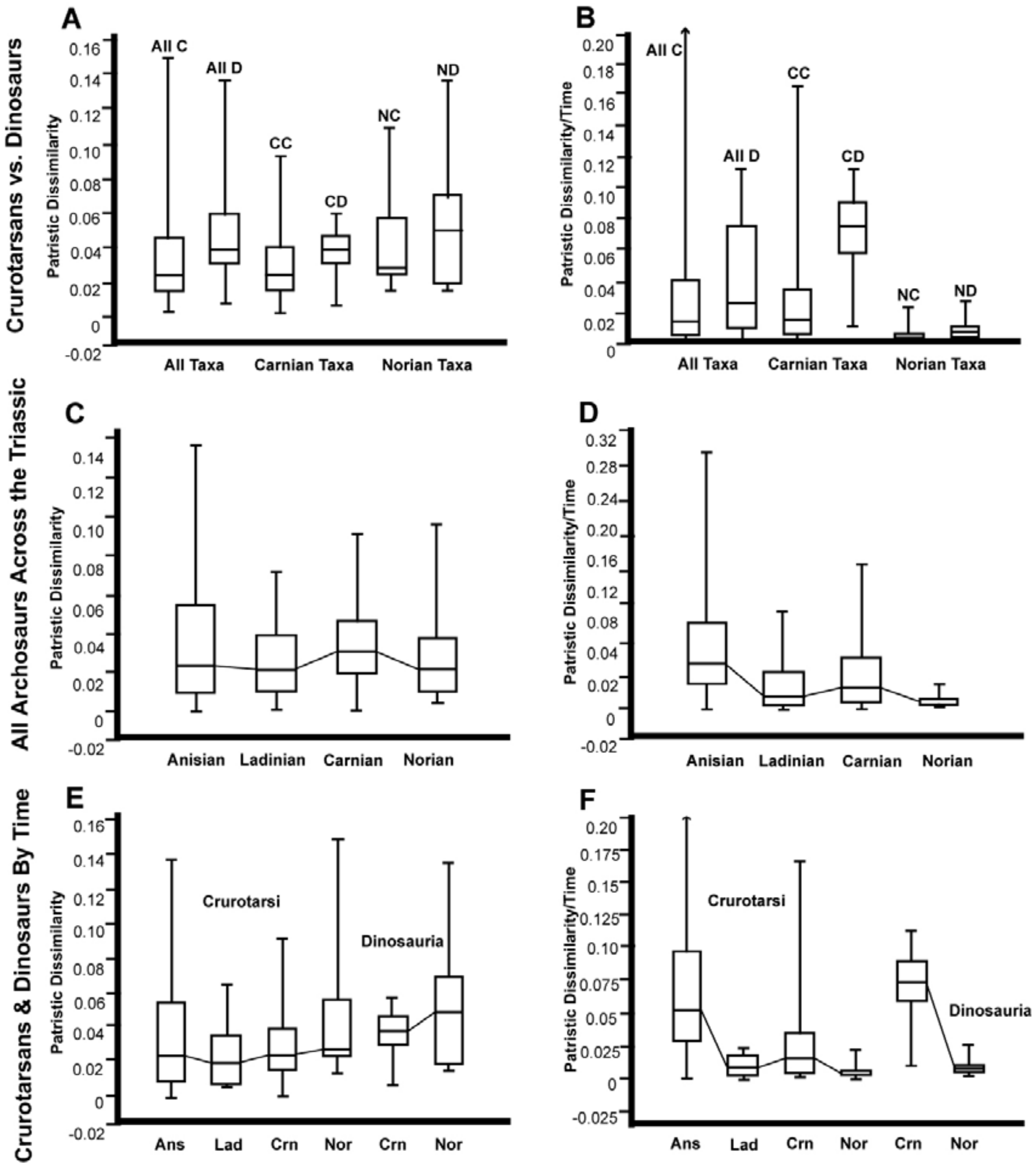

Fig. S2. Plots of rate of morphological character evolution for archosaurs based on two metrics (patristic dissimilarity per branch, dissimilarity/time, see SOM). Rates are based on DELTRAN character optimization. Boxes represent the distribution of real data, with boxes encompassing 25-75 percentiles and the whiskers representing 5-95 percentiles. Plots **A-B** express the evolutionary rates of crurotarsans and dinosaurs (abbreviations as in Fig. 2). Plots **C-D** show disparity against time for all crown group archosaurs, and plots **E-F** show disparity against time for both crurotarsans and dinosaurs. Dinosaurs exhibit higher evolutionary rates than crurotarsans, but these are generally not significant (Table S1). Rates for all archosaurs are either approximately constant (dissimilarity metric) or decrease from an Anisian high to a Norian low (dissimilarity/time metric, Table S4-S5). Patterns within Crurotarsi and Dinosauria mirror the general pattern (Table S6-S9).

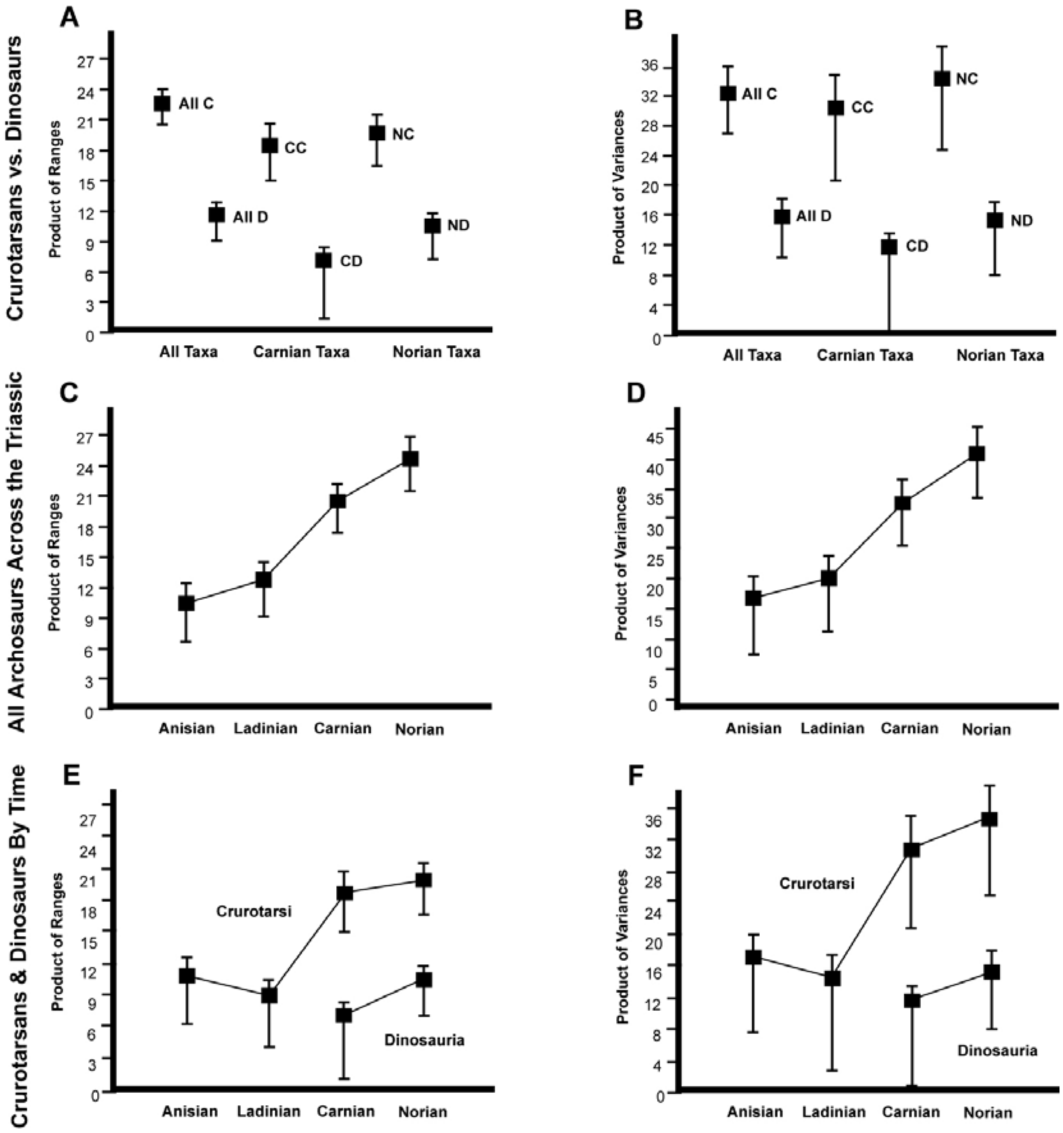

Fig S3. Plots of archosaur morphological disparity based on two metrics (products of ranges and variances, see SOM). Squares represent mean values and error bars denote 95% confidence intervals based on bootstrapping. Plots **A-B** express disparity of crurotarsans and dinosaurs (All C=all Triassic crurotarsans; All D=all Triassic dinosaurs; CC, CD, NC, ND=crurotarsans and dinosaurs subdivided into Carnian and Norian taxa). Plots **C-D** show disparity against time for all crown group archosaurs, and plots **E-F** show disparity against time for both crurotarsans and dinosaurs. Crurotarsans exhibit a significantly higher disparity than dinosaurs when all Triassic taxa (NPMANOVA: $F=29.89$, $p<0.0001$) and Carnian ($F=13.36$, $p=0.0003$) and Norian ($F=20.59$, $p<0.0001$) subdivisions are analyzed. Archosaur disparity increases over time and reaches a statistically-significant peak in the Norian (Tables S23-S24). Crurotarsan and dinosaur disparity generally increase over time but differences between individual time bins are not significant (Tables S25-27).

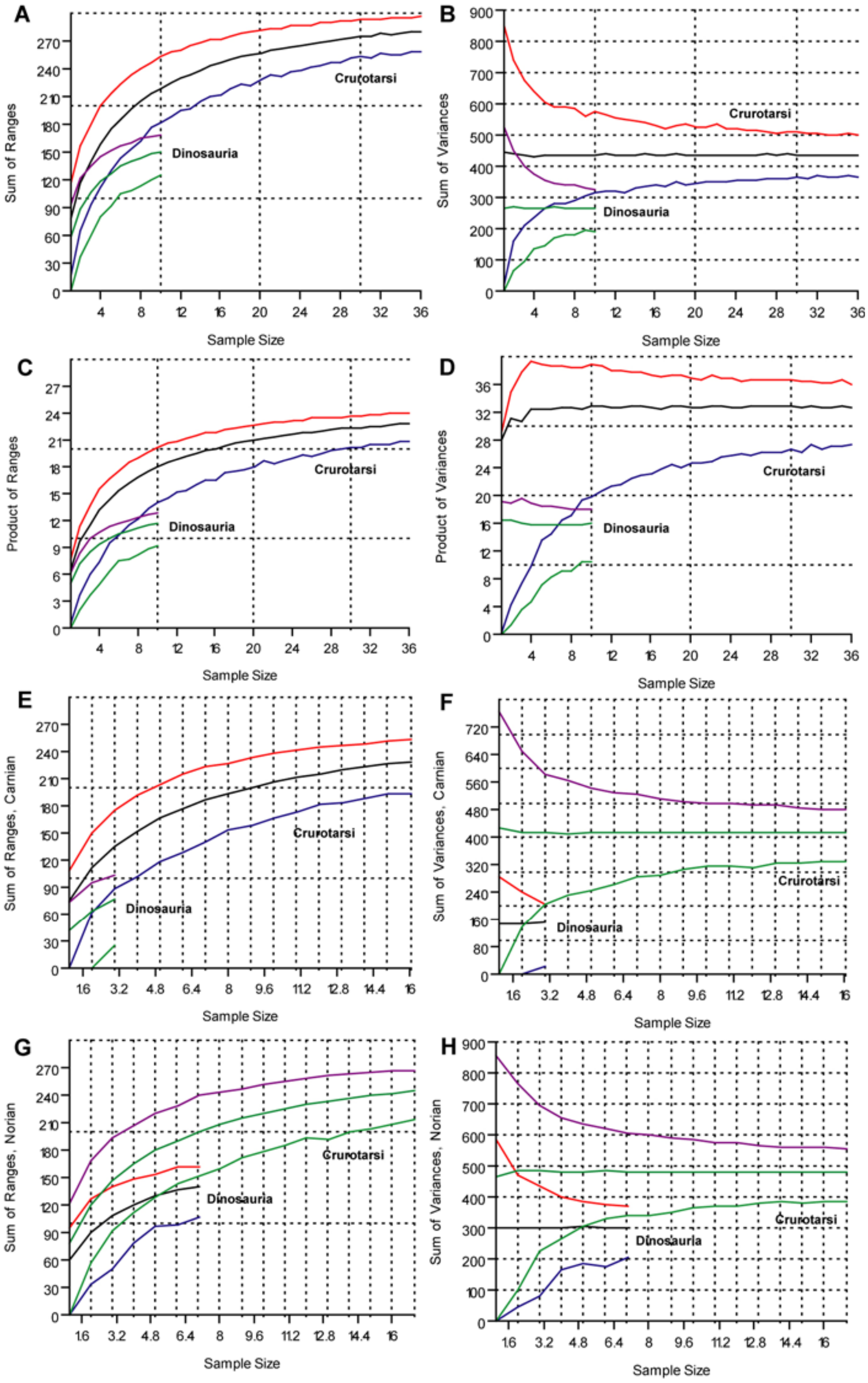

Fig S4. Rarefaction profiles for all four disparity metrics (sum and product of ranges and variances) for all dinosaurs vs. all crurotarsans (**A-D**) and sum based metrics for Carnian (**E-F**) and Norian (**G-H**) subsets. The mean value and 95% confidence intervals are shown for the clades Crurotarsi and Dinosauria. In each plot the top three lines denote Crurotarsi and the bottom three Dinosauria. For all taxa (A-D), in each case the mean value and the 95% confidence intervals for dinosaurs fall outside the 95% confidence intervals for crurotarsans at sample size n=11 (the sample size for dinosaurs). Furthermore, in each case the mean values for dinosaurs lie below the mean values for crurotarsans for all sample sizes (although they do not fall outside of the 95% confidence intervals for crurotarsans at smaller sample sizes). The Carnian and Norian curves (E-H) suggest some caution in interpreting the results because of small sample size. However, all plots show the mean for dinosaurs lying outside the 95% confidence interval for crurotarsans at the smallest sample size being analyzed (n=4 for Carnian dinosaurs, n=8 for Norian dinosaurs). Furthermore, the mean value for dinosaurs is lower than the mean value for crurotarsans at all sample sizes in all plots.

4) Supplementary Tables

Table S1: Evolutionary rates for all Triassic dinosaurs (n=11 taxa and 21 total branches) vs. all Triassic crurotarsans (n=37 taxa and 73 total branches). Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	**Taxon**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.029679635
	Dinosauria	0.039989094
	Test: U=591.5, p=0.1132	
Patristic Dissimilarity Per Branch (DELTRAN)	Crurotarsi	0.031882471
	Dinosauria	0.044832725
	Test: U=504, p=0.01739 **SIG**	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.040383653
	Dinosauria	0.04849764
	Test: U=657, p=0.1993	
Dissimilarity/Time Length of Branch (DEL)	Crurotarsi	0.036789748
	Dinosauria	0.042456461
	Test: U=608, p=0.1515	

Table S2: Evolutionary rates for Triassic dinosaurs and crurotarsans based on a pruned tree of equal sample size (n=11 taxa and 21 branches for both dinosaurs and crurotarsans). Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	**Taxon**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.058421288
	Dinosauria	0.047180987
	Test: U=220.5, p=0.99	
Patristic Dissimilarity Per Branch (DELTRAN)	Crurotarsi	0.060479931
	Dinosauria	0.050187074
	Test: U=202, p=0.6507	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.053753585
	Dinosauria	0.057104755
	Test: U=192, p=0.4812	
Dissimilarity/Time Length of Branch (DEL)	Crurotarsi	0.044167515
	Dinosauria	0.047004929
	Test: U=208, p=0.7628	

Table S3: Evolutionary rates for dinosaurs and crurotarsans separated into Carnian (n=11 branches for Dinosauria, n=28 branches for Crurotarsi) and Norian (n=10 branches for Dinosauria, n=13 branches for Crurotarsi) bins. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	Taxon	Mean
CARNIAN		
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.029753231
	Dinosauria	0.044117573
	Test: U=109, p=0.1649	
Patristic Dissimilarity Per Branch (DELTRAN)	Crurotarsi	0.028779289
	Dinosauria	0.036880489
	Test: U=95.5, p=0.07029	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.024296489
	Dinosauria	0.086505045
	Test: U=40, p=0.0003967 **SIG**	
Dissimilarity/Time Length of Branch (DEL)	Crurotarsi	0.025198191
	Dinosauria	0.072314685
	Test: U=31, p=0.0001318 **SIG**	
NORIAN		
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.024822388
	Dinosauria	0.035447767
	Test: U=51, p=0.4025	
Patristic Dissimilarity Per Branch (DELTRAN)	Crurotarsi	0.042490688
	Dinosauria	0.053580184
	Test: U=55, p=0.558	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.003111071
	Dinosauria	0.006689494
	Test: U=38, p=0.1003	
Dissimilarity/Time Length of Branch (DEL)	Crurotarsi	0.005722763
	Dinosauria	0.009612414
	Test: U=42, p=0.1629	

Table S4: Evolutionary rates for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic. Sample: Anisian (21 branches), Ladinian (23 branches), Carnian (43 branches), Norian (32 branches).

Metric	Interval	Mean
Patristic Dissimilarity Per Branch (ACCTRAN)	Anisian	0.033467125
	Ladinian	0.027518065
	Carnian	0.034971206
	Norian	0.027784328
Patristic Dissimilarity Per Branch (DELTRAN)	Anisian	0.033923592
	Ladinian	0.025983939
	Carnian	0.03280956
	Norian	0.043156558
Dissimilarity/Time Length of Branch (ACC)	Anisian	0.10006172
	Ladinian	0.027548289
	Carnian	0.03940492
	Norian	0.005563558
Dissimilarity/Time Length of Branch (DEL)	Anisian	0.08562899
	Ladinian	0.027826298
	Carnian	0.036221868
	Norian	0.008492123

Table S5: Statistical Tests for metrics in Table S4 (evolutionary rates for all archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=238.5, p=0.9532	U=396, p=0.4316	U=303, p=0.5545
Ladinian	X	X	U=419.5, p=0.3165	U=325.5, p=0.4736
Carnian	X	X	X	U=546.5, p=0.1309
Norian	X	X	X	X

Patristic Dissimilarity Per Branch (DELTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=226.5, p=0.7333	U=384, p=0.3381	U=247.5, p=0.1095
Ladinian	X	X	U=378, p=0.1185	U=243.5, p=0.034 **SIG**
Carnian	X	X	X	U=589, p=0.2914
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=143, p=0.0213 **SIG**	U=309, p=0.0423 **SIG**	U=106, p=0.00003 **SIG**
Ladinian	X	X	U=455, p=0.5997	U=100, p=0.000005 **SIG**
Carnian	X	X	X	U=223, p=0.0000006 **SIG**
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (DELTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=125.5, p=0.0067 **SIG**	U=279.5, p=0.0142 **SIG**	U=86, p=0.000006 **SIG**
Ladinian	X	X	U=426.5, p=0.3637	U=212.5, p=0.008174 **SIG**
Carnian	X	X	X	U=288, p=0.0000187 **SIG**
Norian	X	X	X	X

Table S6: Evolutionary rates for crurotarsans across the Triassic. Sample: Anisian (21 branches), Ladinian (11 branches), Carnian (28 branches), Norian (13 branches).

Metric	Interval	Mean
Patristic Dissimilarity Per Branch (ACCTRAN)	Anisian	0.033467125
	Ladinian	0.028002021
	Carnian	0.029753231
	Norian	0.024822388
Patristic Dissimilarity Per Branch (DELTRAN)	Anisian	0.033923592
	Ladinian	0.02334781
	Carnian	0.028779289
	Norian	0.042490688
Dissimilarity/Time Length of Branch (ACC)	Anisian	0.10006172
	Ladinian	0.011451357
	Carnian	0.024296489
	Norian	0.003111071
Dissimilarity/Time Length of Branch (DEL)	Anisian	0.08562899
	Ladinian	0.009772502
	Carnian	0.025198191
	Norian	0.005722763

Table S7: Statistical Tests for metrics in Table S6 (evolutionary rates for crurotarsans across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=108.5, p=0.7965	U=292, p=0.9758	U=123, p=0.645
Ladinian	X	X	U=151.5, p=0.9502	U=57.5, p=0.4341
Carnian	X	X	X	U=166, p=0.6641
Norian	X	X	X	X

Patristic Dissimilarity Per Branch (DELTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=101.5, p=0.5922	U=275.5, p=0.7161	U=95.5, p=0.1512
Ladinian	X	X	U=121.5, p=0.3179	U=38, p=0.05589
Carnian	X	X	X	U=124, p=0.1072
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=45, p=0.0055 **SIG**	U=159, p=0.00066 **SIG**	U=37, p=0.00045 **SIG**
Ladinian	X	X	U=127, p=0.4082	U=18, p=0.002136 **SIG**
Carnian	X	X	X	U=63, p=0.009 **SIG**
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (DELTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=30, p=0.0007 **SIG**	U=137.5, p=0.0016 **SIG**	U=33, p=0.0003 **SIG**
Ladinian	X	X	U=103, p=0.115	U=48, p=0.1827
Carnian	X	X	X	U=77, p=0.0034 **SIG**
Norian	X	X	X	X

Table S8: Evolutionary rates for dinosaurs across the Triassic. Sample: Carnian (11 branches) and Norian (10 branches). Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	**Interval**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Carnian	0.044117573
	Norian	0.035447767
	Test: U=44, p=0.4597	
Patristic Dissimilarity Per Branch (DELTRAN)	Carnian	0.036880489
	Norian	0.053580184
	Test: U=44, p=0.4597	
Dissimilarity/Time Length of Branch (ACC)	Carnian	0.086505045
	Norian	0.006689494
	Test: U=2, p=0.0002182 **SIG**	
Dissimilarity/Time Length of Branch (DEL)	Carnian	0.072314685
	Norian	0.009612414
	Test: U=4, p=0.0003764 **SIG**	

Table S9: Evolutionary rates of different character partitions (cranial, axial, appendicular). Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	**Taxon**	**Mean**
CRANIAL		
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.038867902
	Dinosauria	0.039849267
	Test: U=586, p=0.2366	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.042009656
	Dinosauria	0.050318919
	Test: U=574, p=0.1941	
AXIAL		
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.029451012
	Dinosauria	0.038246068
	Test: U=728.5, p=0.8041	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.054159315
	Dinosauria	0.050679715
	Test: U=743, p=0.9086	
APPENDICULAR		
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.023041042
	Dinosauria	0.045870535
	Test: U=445, p=0.00357 **SIG**	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.032306887
	Dinosauria	0.056072594
	Test: U=581, p=0.09309	

Table S10: Evolutionary rates of cranial characters for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic.

Metric	**Interval**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Anisian	0.029783658
	Ladinian	0.024734292
	Carnian	0.050049714
	Norian	0.030416452
Dissimilarity/Time Length of Branch (ACC)	Anisian	0.101279265
	Ladinian	0.02056878
	Carnian	0.04209701
	Norian	0.006172134

Table S11: Statistical Tests for metrics in Table S10 (evolutionary rates of cranial characters for archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=208.5, p=0.7818	U=300, p=0.07194	U=268.5, p=0.6692
Ladinian	X	X	U=354.5, p=0.1304	U=303, p=0.7682
Carnian	X	X	X	U=496, p=0.1882
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=139, p=0.04263 **SIG**	U=354, p=0.324	U=160, p=0.00843 **SIG**
Ladinian	X	X	U=331, p=0.06509	U=211, p=0.0409 **SIG**
Carnian	X	X	X	U=217, p=0.000004 **SIG**
Norian	X	X	X	X

Table S12: Evolutionary rates of axial characters for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic.

Metric	**Interval**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Anisian	0.053486506
	Ladinian	0.024827832
	Carnian	0.035302173
	Norian	0.023230282
Dissimilarity/Time Length of Branch (ACC)	Anisian	0.158057934
	Ladinian	0.027298999
	Carnian	0.037222248
	Norian	0.006579546

Table S13: Statistical Tests for metrics in Table S12 (evolutionary rates of axial characters for archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=190, p=0.1618	U=348, p=0.1774	U=224.5, p=0.0609
Ladinian	X	X	U=488.5, p=0.8415	U=345.5, p=0.659
Carnian	X	X	X	U=583.5, p=0.4546
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=142, p=0.01273 **SIG**	U=269, p=0.0124 **SIG**	U=144, p=0.00074 **SIG**
Ladinian	X	X	U=494, p=0.8992	U=277, p=0.1088
Carnian	X	X	X	U=529, p=0.1751
Norian	X	X	X	X

Table S14: Evolutionary rates of appendicular characters for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic.

Metric	**Interval**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Anisian	0.030186388
	Ladinian	0.043214412
	Carnian	0.031478406
	Norian	0.0251658
Dissimilarity/Time Length of Branch (ACC)	Anisian	0.082428939
	Ladinian	0.054650808
	Carnian	0.038982023
	Norian	0.005340517

Table S15: Statistical Tests for metrics in Table S14 (evolutionary rates of appendicular characters for archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=219, p=0.4597	U=443, p=0.9089	U=265, p=0.1998
Ladinian	X	X	U=439.5, p=0.3203	U=268, p=0.05584
Carnian	X	X	X	U=566.5, p=0.1949
Norian	X	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=197.5, p=0.2192	U=284, p=0.01695 **SIG**	U=98, p=0.0000156 **SIG**
Ladinian	X	X	U=433, p=0.2807	U=131, p=0.0000291 **SIG**
Carnian	X	X	X	U=348, p=0.0002761 **SIG**
Norian	X	X	X	X

Table S16: Evolutionary rates of different character partitions for dinosaurs (all Triassic taxa).

Metric	Partition	Mean
Patristic Dissimilarity Per Branch (ACCTRAN)	Cranial	0.039849267
	Axial	0.038246068
	Appendicular	0.045870535
Dissimilarity/Time Length of Branch (ACC)	Cranial	0.050318919
	Axial	0.050679715
	Appendicular	0.056072594

Table S17: Statistical Tests for metrics in Table S16 (evolutionary rates of character partitions for dinosaurs). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Cranial	Axial	Appendicular
Cranial	X	U=163, p=0.2252	U=197, p=0.7444
Axial	X	X	U=161, p=0.1378
Appendicular	X	X	X

Dissimilarity/Time Length of Branch (ACCTRAN)

	Cranial	Axial	Appendicular
Cranial	X	U=139, p=0.06595	U=209, p=0.9896
Axial	X	X	U=148, p=0.07011
Appendicular	X	X	X

Table S18: Mean and median values for number of changes of each character state among crurotarsans and dinosaurs. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Taxon	**Mean**	**Median**
Crurotarsi	2.40	2
Dinosauria	1.26	1
Test: U=40600, p=0.000000007		

Table S19: Mean and median values for number of changes of each character state for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Interval	**Mean**	**Median**
Anisian	1.25	1
Ladinian	1.20	1
Carnian	1.51	1
Norian	1.30	1

Table S20: Statistical Tests for metrics in Table S19 (number of changes per charater state for all archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Patristic Dissimilarity Per Branch (ACCTRAN)

	Anisian	Ladinian	Carnian	Norian
Anisian	X	U=15600 p=0.552	U=24800, p=0.04 **SIG**	U=27700, p=0.671
Ladinian	X	X	U=26600, p=0.05 **SIG**	U=29700, p=0.2665
Carnian	X	X	X	U=49500, p=0.04 **SIG**
Norian	X	X	X	X

Table S21: Morphological disparity for all Triassic dinosaurs (n=11) vs. all Triassic crurotarsans (n=37). Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

Metric	**Taxon**	**Value**	**95% Error Bars**
Sum of Ranges	Crurotarsi	280.61	258.07, 297.20
	Dinosauria	150.28	124.86, 169.07
Product of Ranges:	Crurotarsi	22.84156468	20.7705759, 24.0588601
	Dinosauria	11.63466409	9.189392856, 12.78198847
Sum of Variances:	Crurotarsi	433.826591	366.599107, 499.150394
	Dinosauria	266.339431	191.400406, 326.514645
Prod of Variances:	Crurotarsi	32.65560672	27.22647996, 36.08337976
	Dinosauria	15.89868228	10.4697644, 18.01337664

Statistical Test: We can reject the null hypothesis of equal means for dinosaurs and crurotarsans ($F=29.89$, $p<0.0001$, 10,000 permutations).

Rarefaction: See Fig. S4.

Table S22: Morphological disparity for dinosaurs and crurotarsans separated into Carnian (n=4 dinosaur taxa, n=17 crurotarsan taxa) and Norian (n=8 dinosaur taxa, n=18 crurotarsan taxa) bins. Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

Metric	Taxon	Value	95% Error Bars
CARNIAN			
Sum of Ranges	Crurotarsi	228.28	194.11, 253.09
	Dinosauria	76.44	25.05, 103.48
Product of Ranges:	Crurotarsi	18.71	15.00, 20.51
	Dinosauria	7.01	1.05, 8.10
Sum of Variances:	Crurotarsi	414.07	329.17, 481.95
	Dinosauria	149.37	20.81, 206.29
Prod of Variances:	Crurotarsi	30.64	20.81, 34.87
	Dinosauria	11.72	0.27, 13.35
NORIAN			
Sum of Ranges	Crurotarsi	244.74	213.86, 267.37
	Dinosauria	140.20	106.75, 162.40
Product of Ranges:	Crurotarsi	19.89	16.65, 21.50
	Dinosauria	10.42	7.15, 11.56
Sum of Variances:	Crurotarsi	480.16	387.20, 554.9137
	Dinosauria	301.01	206.17, 368.95
Prod of Variances:	Crurotarsi	34.71	24.90, 38.66
	Dinosauria	15.40	8.01, 17.70

Statistical Tests: We can reject the null hypothesis of equal means in the Carnian ($F=13.36$, $p=0.0003$, 10,000 permutations) and in the Norian ($F=20.59$, $p<0.0001$, 10,000 permutations).

Rarefaction: See Fig. S4.

Table S23: Morphological disparity for all crown group Archosauria (all taxa: dinosaurs, crurotarsans, pterosaurs, dinosauromorphs) across the Triassic. Sample: Anisian (7 taxa), Ladinian (10 taxa), Carnian (24 taxa), Norian (33 taxa).

Metric	**Interval**	**Value**	**95% Error Bars**
Sum of Ranges	Anisian	138.508155	94.631283, 169.029304
	Ladinian	160.877253	125.280301, 184.988037
	Carnian	253.401445	223.180339, 276.436753
	Norian	302.968051	271.089949, 329.750184
Product of Ranges:	Anisian	10.71971775	6.420813065, 12.25626148
	Ladinian	12.92521707	9.077717242, 14.45870001
	Carnian	20.88137732	17.64386903, 22.629314
	Norian	25.19296811	21.79562961, 27.20447582
Sum of Variances:	Anisian	315.532011	142.537415, 472.978162
	Ladinian	327.565245	215.669606, 408.176937
	Carnian	446.336553	390.867027, 496.593458
	Norian	550.781429	497.434131, 600.094985
Prod of Variances:	Anisian	16.96923769	7.726362816, 19.99005668
	Ladinian	20.22696931	10.97986852, 23.67672258
	Carnian	32.68264271	25.164429, 36.63862937
	Norian	41.13309546	33.9505534, 45.16277597

Table S24: Statistical Tests for metrics in Table S23 (disparity of all archosaurs across the Triassic). Values denote pairwise tests between two intervals. Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

	Anisian	Ladinian	Carnian	Norian
Anisian	X	P=0.4013	P=0.2823	P=0.031 **SIG**
Ladinian	X	X	P=0.6261	P=0.3615
Carnian	X	X	X	P=0.0501 **SIG**
Norian	X	X	X	X

Table S25: Morphological disparity for all crurotarsans across the Triassic. Sample: Anisian (7 taxa), Ladinian (6 taxa), Carnian (17 taxa), Norian (18 taxa).

Metric	**Interval**	**Mean**	**95% Error Bars**
Sum of Ranges	Anisian	138.66	90.94, 169.03
	Ladinian	107.38	63.35, 136.78
	Carnian	228.28	194.11, 253.09
	Norian	244.74	213.86, 267.37
Product of Ranges:	Anisian	10.77	6.41, 12.42
	Ladinian	9.02	3.98, 10.33
	Carnian	18.71	14.99, 20.51
	Norian	19.89	16.65, 21.50
Sum of Variances:	Anisian	316.69	141.94, 475.33
	Ladinian	203.41	83.98, 295.14
	Carnian	414.07	329.17, 481.95
	Norian	480.16	387.20, 554.91
Prod of Variances:	Anisian	17.07	7.87, 20.03
	Ladinian	14.47	3.21, 17.36
	Carnian	30.64	20.81, 34.87
	Norian	34.71	24.90, 38.66

Table S26: Statistical Tests for metrics in Table S25 (disparity of crurotarsans across the Triassic). Values denote pairwise tests between two intervals. Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

	Anisian	Ladinian	Carnian	Norian
Anisian	X	P=0.2585	P=0.092	P=0.0688
Ladinian	X	X	P=0.9129	P=0.3082
Carnian	X	X	X	P=0.4363
Norian	X	X	X	X

Table S27: Morphological disparity for all dinosaurs across the Triassic. Sample: Carnian (4 taxa), Norian (8 taxa). Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

Metric	**Interval**	**Value**	**95% Error Bars**
Sum of Ranges	Carnian	76.44	25.05, 103.48
	Norian	140.20	106.75, 162.40
Product of Ranges:	Carnian	7.01	1.05, 8.10
	Norian	10.42	7.15, 11.56
Sum of Variances:	Carnian	149.37	20.81, 206.29
	Norian	301.01	206.17, 368.95
Prod of Variances:	Carnian	11.72	0.27, 13.35
	Norian	15.40	8.01, 17.70

Statistical Test: We cannot reject the null hypothesis of equal means in the Carnian and Norian (F=0.8731, p=0.1995, 10,000 permutations).

Table S28: Evolutionary rates for all Triassic ornithodirans (n=24 taxa and 48 total branches) vs. all Triassic crurotarsans (n=37 taxa and 73 total branches). Statistical tests are Mann-Whitney U tests, which tests for significant difference from the null hypothesis of equal distributions of rates among bins.

Metric	**Taxon**	**Mean**
Patristic Dissimilarity Per Branch (ACCTRAN)	Crurotarsi	0.029679635
	Ornithodira	0.035570466
	Test: U=1530, p=0.3186	
Patristic Dissimilarity Per Branch (DELTRAN)	Crurotarsi	0.031882471
	Ornithodira	0.039068329
	Test: U=1327, p=0.03673 **SIG**	
Dissimilarity/Time Length of Branch (ACC)	Crurotarsi	0.040383653
	Ornithodira	0.0.03895681
	Test: U=1531, p=0.3225	
Dissimilarity/Time Length of Branch (DEL)	Crurotarsi	0.036789748
	Ornithodira	0.035710409
	Test: U=1472, p=0.1905	

Table S29: Morphological disparity for all Triassic ornithodirans (n=24) vs. all Triassic crurotarsans (n=37). Statistical test is a NPMANOVA test, which tests for significant difference from the null hypothesis of equal group variances.

Metric	**Taxon**	**Value**	**95% Error Bars**
Sum of Ranges	Crurotarsi	280.61	258.07, 297.20
	Ornithodira	215.97	195.71, 232.80
Product of Ranges:	Crurotarsi	22.84156468	20.7705759, 24.0588601
	Ornithodira	17.06806	15.21906, 18.27999
Sum of Variances:	Crurotarsi	433.826591	366.599107, 499.150394
	Ornithodira	306.5664	296.3947, 431.2113
Prod of Variances:	Crurotarsi	32.65560672	27.22647996, 36.08337976
	Ornithodira	22.69042	18.6379, 25.07318

Statistical Test: We can reject the null hypothesis of equal means for dinosaurs and crurotarsans ($F=2.658$, $p<0.0001$, 10,000 permutations).

5) Supplementary References

S1. A.M. Báez, C.A. Marsicano, *Ameghiniana* **38**, 271 (2001).
S2. S.L. Brusatte, *The Higher-Level Phylogeny of Archosauria* (Unpublished MSc Thesis, Univ. of Bristol, 2007).
S3. P.C. Sereno, *Mem. Soc. Vert. Paleo*. **2**, 1 (1991).
S4. A.W.A. Kellner, *Geol. Soc. London. Sp. Pub*. **217**, 105 (2003).
S5. A. Hungerbühler, *Palaeontology* **45**, 377 (2000).
S6. W.G. Parker, *J. Syst. Palaeontol*. **5**, 41 (2007).
S7. J.M. Clark, X. Xu, C.A. Forster, Y. Wang, *Nature* **430**, 1021 (2004).
S8. R.J. Butler, R.M. Smith, D.B. Norman, *Proc. R. Soc. London B* **274**, 2041 (2007).
S9. P.C. Sereno, *Science* 284, **2137** (1999).
S10. G.D. Wesley-Hunt, *Paleobiol*. **31**, 25 (2005).
S11. M. Foote, *Paleobiol*. **20**, 320 (1994).
S12. M. Foote, *Paleobiol*. **21**, 273 (1995).
S13. M. Foote, *Science* **274**, 1492 (1996).
S14. P.J. Wagner, *Paleobiol*. **23**, 115 (1997).
S15. M.J. Benton, *Phil. Trans. Roy. Soc. London B* **354**, 1423 (1999).
S16. M.J. Benton, in *The Dinosauria* (Univ. of California Press, Berkeley, CA, ed. 2, 2004).
S17. M.J. Benton, in *In the Shadow of the Dinosaurs* (Cambridge Univ. Press, 1994).
S18. D.B. Weishampel, P. Dodson, H. Osmolska, Eds. *The Dinosauria* (Univ. of California Press, Berkeley, CA, ed. 2, 2004).
S19. S. Nesbitt, *Bull. Am. Mus. Nat. Hist*. **302**, 1 (2007).
S20. S.E. Peters, *PNAS (USA)* 102, 12326 (2005).
S21. M. Ruta, P.J. Wagner, M.I. Coates, *Proc. R. Soc. London B* **273**, 2107 (2006).
S22. D.J. Gower, M. Wilkinson, *Proc. R. Soc. London B* **263**, 1399 (1996).
S23. F. Gradstein, J. Ogg, A. Smith, *A Geologic Time Scale* (Cambridge Univ. Press, 2004).
S24. S. Furin, *et al.*, *Geology* **34**, 1009 (2006).
S25. M.A. Wills, D.E.G. Briggs, R.A. Fortey, *Paleobiol*. **20**, 93 (1994).
S26. R. Lupia, *Paleobiol*. **25**, 1 (1999).
S27. A. Stockmeyer Lofgren, R.E. Plotnick, P.J. Wagner, *Paleobiol*. **29**, 349 (2003).
S28. M.A. Wills, *Biol. J. Linn. Soc*. **65**, 455 (1998).
S29. M.J. Anderson, *Austral Ecology* **26**, 32 (2001).
S30. P.J. Wagner, M. Ruta, M.I. Coates, *Proc. R. Soc. London B* **273**, 2113 (2006).
S31. P.J. Wagner, *Evolution*. **54**, 365 (2000).

6) Character List

A) HIGHER-LEVEL ARCHOSAUR PHYLOGENY, Brusatte, 2007

1. Skull, length: less than (0) or greater than (1) 50% length of presacral column.

2. Antorbital fenestra, shape: elliptical or circular (0); triangular, with elongate and narrow anterior point (1).

3. Orbit, anteroposterior length: less (0) or greater (1) than 25% skull length.

4. Orbit, shape: circular or elliptical (0); tall and narrow, with maximum height more than 1.5 times maximum width (1).

5. External naris, length of longest dimension: less (0) or greater (1) than longest dimension of antorbital fenestra.

6. External nares, elements separating opposing nares on dorsal midline: premaxilla only (0); premaxilla and nasal (1); nasal only (2).

7. Lateral temporal fenestra, size: greater or equal (0) or smaller (1) than supratemporal fenestra.

8. Lateral temporal fenestra, shape: elliptical (0); triangular, with dorsal margin much shorter than ventral margin (1).

9. Supratemporal fenestra, orientation: exposed primarily dorsally (0); widely exposed laterally (1).

10. Supratemporal fenestra, extent of surrounding fossa: limited (0); extensive, present on squamosal, postorbital, parietal, and sometimes the frontal (1).

11. Skull, slit-like fenestra between premaxilla and maxilla (greatest dimension greater than three times lesser dimension): absent (0); present (1).

12. Premaxilla, inclination of anterior border: vertical (0); slopes posterodorsally (1).

13. Premaxilla, length of ventral margin compared to ventral margin of maxilla: shorter (0); longer, premaxilla forms elongate snout and maxilla unreduced (1); longer, maxilla reduced in size (2).

14. Premaxilla, ventral ascending process articulating with maxilla, form: absent or very short (0); elongate and finger-like (1); short and triangular (2).

15. Premaxilla, ventral ascending process articulating with maxilla, extent: terminates ventral to (0) or posterior to (1) external naris.

16. Premaxilla, dorsal ascending process articulating with nasal to form internarial bar, length: shorter (0) or longer (1) than ventral margin of premaxilla body.

17. Premaxilla, dentition: present, bearing teeth (0); absent, edentulous (1).

18. Premaxilla, articulation with maxilla, form of ventral border: at same level as maxilla ventral border (0); angled relative to maxilla ventral border, forming an arch between the elements (1).

19. Maxilla, anterior ramus extending anterior to ascending ramus: absent, anterior surface of maxilla smoothly convex (0); present, distinct step separating anterior portion of maxilla and ascending ramus (1).

20. Maxilla, anteroposterior length of base of ascending ramus: greater (0) or less (1) than one half depth of maxillary main body at anterior edge of antorbital fenestra.

21. Maxilla, form of antorbital fossa on lateral surface: shallowly excavated and not set apart by strong ridge (0); deeply excavated and demarcated by a strong ridge (1).

22. Maxilla, length of portion of bone anterior to anterior margin of antorbital fenestra: longer (0) or shorter (1) than portion posterior to anterior margin of antorbital fenestra.

23. Maxilla, articulation with opposing maxilla on palate to form secondary bony palate: absent (0); present (1).

24. Maxilla, dentition: present, bearing teeth (0); absent, edentulous (1).

25. Nasal, position of anterior portion in lateral view: below or at same level as skull roof (0); elevated above skull roof, giving the skull a “roman nose” appearance (1).

26. Nasal, rugose lateral ridge: absent (0); present (1).

27. Nasal, midline depression in dorsal view: absent (0); present (1).

28. Lacrimal, exposure on the skull roof: absent (0); present (1).

29. Skull roof (nasal and frontals), sculpturing: present, consisting of marked grooves and ridges (0); absent, skull roof smooth (1).

30. Prefrontal, contact with nasal, extent: broad (0); reduced or excluded by frontal-lacrimal contact (1).

31. Prefrontal, descending process forming anterodorsal rim of orbit, size: elongate, extends approximately 1/3-1/2 length of preorbital bar (0); shortened, only slightly contributes to preorbital bar (1).

32. Prefrontal, posterior process underlying frontal dorsal to orbit: absent (0); present (1).

33. Frontal, contribution to dorsal orbital rim: present (0); absent, excluded by an enlarged prefrontal contacting the postfrontal/postorbital lateral to frontal (1).

34. Frontal, sagittal crest along midline in dorsal view: absent (0); present (1).

35. Frontal, dorsal surface, participation in supratemporal fossa: absent (0); present (1).

36. Postfrontal: present (0); present but reduced & does not articulate with parietal (1); absent (2).

37. Parietals, midline suture between opposing elements: present, butt joint (0); partially obliterated (1); absent, parietals fused on midline (2).

38. Parietals, posteroventral edge, width: less (0) or greater (1) than ½ width of occiput.

39. Parietals, shape of posterior margin in dorsal view: v-shaped (0); straight (1).

40. Parietal, sagittal crest along midline in dorsal view: absent (0); present (1).

41. Jugal, shape: triradiate (0); elongate and rod-like (1).

42. Jugal, participation in posterior edge of antorbital fenestra: present (0); absent, excluded by maxilla-lacrimal contact (1).

43. Jugal, lateral surface, form: smooth or marked by a shallow rim delimiting the antorbital fossa (0); ornamented by a deep and rugose ridge delimiting the antorbital fossa, which is continuous with a similar ridge on the maxilla (1).

44. Postorbital-Jugal postorbital bar, form: straight or curved (0); stepped, with distinct anterior projection on postorbital (1).

45. Postorbital and Squamosal, position of dorsal bar: at same level as ventral processes of bones (0); distinctly offset from ventral processes, forming overhanging brow over lateral temporal fenestra (1).

46. Squamosal, ridge along dorsal surface along edge of supratemporal fossa: absent (0); present (1).

47. Squamosal, position of posterior process: at same level or dorsal to anterior process (0); below anterior process and set off by distinct step (1).

48. Squamosal, ventral process: present, forms posterodorsal border of lateral temporal fenestra (0); present, does not participate widely in lateral temporal fenestra (1); absent (2).

49. Squamosal, ridge trending posteroventrally on lateral surface of ventral ramus: absent (0); present (1).

50. Squamosal, deep pit on the posterodorsal corner of the lateral surface: absent (0); present (1).

51. Squamosal ventral process and Quadratojugal dorsal process, orientation: subvertical or broadly convex anteriorly (0); distinct process on squamosal ventral process projecting into infratemporal fenestra (1); slopes anteriorly to form a triangular projection into the infratemporal fenestra comprised of both elements (2); triangular projection completely divides infratemporal fenestra into two openings (3).

52. Quadrate and quadratojugal, orientation: roughly vertical, do not reach upper margin of infratemporal fenestra (0); sloping anterodorsally at approximately 45 degrees, reach upper margin of infratemporal fenestra (1); sloping strongly posterodorsally (2).

53. Quadrate, quadrate foramen: present (0); absent (1).

54. Quadrate, distal articular surface, form of condyles: two convex condyles separated by a groove (0); one convex condyle (1).

55. Quadrate, distal articular surface, shape: oval, with mediolateral long axis (0); square (1). New character, originally described by Nesbitt (2007).

56. Ectopterygoid, position relative to transverse flange of pterygoid: ventral (0); dorsal (1).

57. Ectopterygoid, lateral process for articulation with jugal, length: anteroposteriorly shorter (0) or longer or equal to (1) medial process.

58. Ectopterygoid, form of articulation with jugal: single-headed (0); double-headed (1).

59. Braincase, size of posttemporal fenestra between parietal, supraoccipital, and exoccipital-opisthotic: large (0); reduced to small fissure or entirely closed (1).

60. Braincase, occipital condyle, shape: spherical (0); dorsoventrally-compressed crescent shape (1).

61. Braincase, basal tubera, orientation: vertical, located ventral to occipital condyle (0); horizontal, located at same level as occipital condyle and flooring endocranial cavity (1).

62. Parabasisphenoid, dorsoventral depth: short and rod-like (0); deep and wedge-shaped, with trough-like median pharyngeal recess (1).

63. Parabasisphenoid, position of foramina for cerebral branches of internal carotid artery: posterior surface (0); posterolateral surface (1); anterolateral surface (2).

64. Parabasisphenoid, position of basipterygoid processes: ventral to basal tubera (0); at same level of basal tubera (=”horizontal parabasisphenoid”) (1).

66. Exoccipital-opisthotic, form of lateral surface: smooth (0); marked by subvertical crest, with hypoglossal foramina anterior to crest (1); marked by subvertical crest, with hypoglossal foramina posterior to crest (2).

67. Exoccipitals, contact of opposing elements along floor of endocranial cavity: present (0); absent (1).

68. Opisthotic, form of border of perilymphatic foramen: incompletely ossified (0); entirely ossified such that the ventral ramus of the opisthotic forms a perilymphatic loop (1).

69. Opisthotic, position and orientation of perilymphatic foramen: medial position, perilymphatic duct transmitted posteromedially or posteriorly (0); lateral position, duct transmitted posterolaterally or laterally (1).

70. Prootic, form of openings for trigeminal nerve and middle cerebral vein: combined into single foramen (0); partially or completely subdivided into separate foramina by a process of the prootic (1).

71. Dentary, teeth: present up to anterior tip (0); absent at anterior tip but present posteriorly (1); completely absent (2); present at anterior tip but first tooth slightly inset (3).

72. Dentary, expansion of anterior region relative to main body: absent (0); present (1).

73. Dentary, length of symphysis: anteroposteriorly short (0); anteroposteriorly expanded and deep (1).

74. Surangular, lateral ridge: present (0); absent (1).

75. Surangular, foramen: absent (0); present (1).

76. Articular, medial process: present (0); absent (1).

77. Cervical vertebrae, anterior centrum length:height ratio: less (0) or greater (1) than 2.0.

78. Cervical vertebrae, length of anterior centra: less (0) or greater (1) than length of middorsal centra. 79. Cervical vertebrae, level of anterior articular face: at same level as posterior face or slightly offset across entire column (0); anterior centra dorsally offset from posterior face, resulting in a parallelogram shape of individual anterior cervicals (1); all centra dorsally offset from posterior face, resulting in a strong S-shaped neck overall (2).

80. Cervical vertebrae, form of ventral margin in lateral view: straight or slightly concave, constriction less than 35% of centrum height at midpoint (0); strongly concave, resulting in a highly waisted centrum, constriction greater than 35% height of centrum at midpoint (1).

81. Cervical vertebrae, epipophyses in postaxial anterior elements: absent (0); present (1); present across cervical column (2).

82. Cervical vertebrae, form of parapophyses: single structure (0); divided into separate dorsal and ventral articular surfaces (1).

83. Cervical vertebrae, pleurocoels or similar depressions on lateral surface: absent (0); present (1).

84. Dorsal vertebrae, height of neural spines: less (0) or greater (1) than four times centrum height.

85. Dorsal vertebrae, spine tables (expanded apex) on neural spines: absent (0); present (1). 86. Dorsal vertebrae, deep fossa beneath region where posterior centroparapophyseal and paradiapophyseal laminae meet: absent (0); present (1).

87. Dorsal vertebrae, hyposphene-hypantrum accessory articulations: absent (0); present (1).

88. Sacral vertebrae, number: two (0); three (1); four or more (2).

89. Sacral vertebrae, extent of fusion: absent or limited to centra (0); extensive, zygapophyses completely fused (1).

90. Sacral vertebrae, form of centrum rims: prominent, individual sacrals well demarcated (0); reduced, individual sacrals poorly demarcated and entire structure cylindrical (1).

91. Caudal vertebrae, midcaudal elements, accessory anterior projection on neural spine: absent (0); present (1).

92. Cervical ribs, length and shape: long and slender (0); short and stout (1).

93. Sacral ribs, anteroposterior length: long, forming broad plate that expands laterally in dorsal view (0); short, forming a waisted projection in dorsal view (1).

94. Sacral ribs, first rib, location of articulation on ilium: midsection of iliac blade (0); anterior end of preacetabular process (="anterior crest") (1).

95. Sacral ribs, form and articulation of first rib with ilium: plate-like, contacts ilium in straight parasagittal articulation (0); distal end slightly dorsally expanded relative to shaft (1); entire rib dorsoventrally expanded and contacts ilium in C-shaped articulation (2).

96. Dorsal osteoderms: present, with a single osteoderm or osteoderm pair per vertebra (0); present, with multiple osteoderms per vertebra (1); absent (2).

97. Dorsal osteroderms, texture: smooth (0); sculptured (1); osteoderms absent (2).

98. Forelimb, length relative to hindlimb: greater than (0) or less than (1) 60%; longer than hindlimb (2).

99. Scapula, depth of distal expansion: less (0) or greater (1) than 2.5 times narrowest region of shaft.

100. Scapula-coracoid, notch on dorsal margin between scapula and coracoid: absent or small (0); present and large (1); present and large, coracoid resembles crescentic plate (2). 101. Coracoid, position of contribution to glenoid: at same level (0) or ventral (1) to scapular glenoid.

102. Coracoid, postglenoid process: absent (0); present and small (1); present and hypertrophied (2).

103. Interclavicle: present (0); absent (1).

104. Clavicle: present (0); rudimentary or absent (1).

105. Humerus, width of proximal end: greater (0) or less (1) than twice midshaft width.

106. Humerus, form of medial margin under inner tuberosity: confluent with shaft (0); strongly arched and angled approximately 45 degrees to shaft (1).

107. Humerus, extent of deltopectoral crest: less than (0) or greater than (1) 35% of the length of the bone; greater than 50% length of bone (2).

108. Humerus, form of deltopectoral crest: rounded (0); subrectangular, with angular corners (1).

109. Manual digits IV and V: elongated, 3+ and 3 phalanges, respectively (0); reduced, IV shorter than metacarpal III and with three or fewer phalanges and V with two or fewer phalanges (1); manual digit IV greatly elongated, five to ten times the length of other digits, and manual digit V absent (2).

110. Acetabulum, antritrochanter for articulation with the femur: absent or restricted to ischium (0); present on both ilium and ischium, with an overall kidney shape (1).

111. Ilium, ratio of blade length to depth above acetabulum: less than (0) or greater than (1) 4.5

112. Ilium, form of dorsal margin: straight or convex (0); concave and saddle-shaped (1).

113. Ilium, form of the ventral margin of the acetabular contribution: convex, acetabulum closed (0); straight or concave, acetabulum slightly perforate (1); straight or concave, acetabulum completely open (2).

114. Ilium, ridge extending from the dorsal margin of the acetabulum: absent (0); present and extending dorsally (1); present, extending anteriorly onto the preacetabular process (2).

115. Ilium, ridge extending from the dorsal margin of the acetabulum, orientation at its dorsal termination: oriented anteriorly only (0); oriented anteriorly and posteriorly (1); ridge absent (2).

116. Ilium, length of preacetabular process: shorter (0) or equal or longer (1) than postacetabular process.

117. Ilium, form of preacetabular process: large and deep (0); small, shallow, and finger-like (1).

118. Ilium, preacetabular process, extent of anterior margin: terminates posterior (0) or anterior (1) to anterior margin of pubic peduncle.

119. Ilium, deep fossa on preacetabular process: absent (0); present (1).

120. Ilium, form of the ventral margin of the postacetabular process: unsculptured or excavated by a small furrow (0); excavated by a deep cavity (1); excavated by a brevis fossa (sensu Novas 1992, 1996) (2).

121. Ilium, lamina of bone connecting preacetabular and postacetabular processes and rising dorsally above each: absent (0); present (1).

122. Pubis, form: plate-like (0); rod-like and curved posteriorly (1); rod-like and straight (2); very thin rod (3).

123. Pubis, length: shorter than ischium (0); longer than ischium but shorter than three times acetabulum diameter (1); longer than three times acetabulum diameter (2).

124. Pubis, form of posterior portion of acetabular margin: continuous with anterior margin and forms articular surface for femur (0); recessed from anterior margin and forms nonarticular surface (1).

125. Pubis, ridge on the lateral surface: absent (0); present (1).

126. Pubis, extent of medioventral lamina (obturator flange): extensive, measuring approximately entire length of bone (0); reduced, measuring approximately 50-70% length of bone (1); very reduced, measuring less than 50% length of bone (2).

127. Pubis, form of distal end: unexpanded or slightly expanded (0); expanded into small pubic boot (1); expanded into large pubic boot with a posterior projection (2); expanded into large pubic boot that is greater than 1/3 length of the shaft (3).

128. Ischium, anteroposterior length of shaft: greater or equal (0) or less than (1) length of pubis.

129. Ischium, form of medioventral lamina (obturator process): well-developed, plate-like, and dorsoventrally deep (0); reduced, restricted to proximal third of bone, and dorsoventrally shallow (1).

130. Ischium, form of distal end: plate-like (0); rod-like with no distal expansion (1); expanded into ischial boot (2); expanded into large ischial boot with prominent posterior projection (3).

131. Femur, shape of head in lateral view: rounded (0); hook-shaped (1).

132. Femur, form of head: confluent with shaft (0); slightly offset from shaft by ventral notch (1); distinctly set off from shaft, with an angular mesiodistal corner (2).

133. Femur, angle of head relative to shaft: less than 45 degrees (0); greater than 45 degrees (1).

134. Femur, emargination on the anterolateral side of the femoral head: absent (0); present (1).

135. Femur, shape of proximal articular surface: oval or wedge-shaped (0); subtriangular, due to straight anterior and posterior faces and tapering lateral corner (1).

136. Femur, extent of smooth articular surface for acetabulum: restricted to the proximal portion of the head (0); extends ventrally under head (1).

137. Femur, transverse groove on proximal articular surface: absent (0); present and shallow (1); present and deep (2).

138. Femur, medial margin in proximal view, tubera for femoral head ligaments: two well-defined medial tubera (0); single well-defined medial tuber (1); tubera absent, medial margin of femur gently convex (2).

139. Femur, form of anteromedial tuber on medial margin in proximal view: small and conical (0); large and hook-like (1).

140. Femur, tuber on lateral margin in proximal view: present (0); absent (1).

141. Femur, fossa trochanterica (groove inset on posterolateral corner of proximal surface): absent or shallow (0); present and distinct (1).

142. Femur, cranial (=lesser) trochanter: absent (0); present (1).

143. Femur, trochanteric shelf: absent (0); present (1).

144. Femur, greater trochanter, form of dorsal margin: rounded (0); angular, approaching 90 degrees (1).

145. Femur, fourth trochanter: present (0); absent (1).

146. Femur, fibular condyle, size compared to tibial condyle: smaller (0); larger (1).

147. Femur, groove between lateral condyle and fibular condyle: absent (0); present (1).

148. Tibia, length: less than or equal (0) or greater (1) than length of femur.

149. Tibia, cnemial crest: absent or very low (0); present and projecting anteriorly (1); present and projecting anterolaterally (2).

150. Tibia, fibular crest: absent (0); present (1).

151. Tibia, form of lateral surface of the distal end: flat (0); excavated by a groove (1).

152. Tibia, median crest on posterior surface of distal end: absent (0); present (1).

153. Tibia, extent of posterior process for articulation with astragalus: at same level as distal anterior surface (0); projecting ventrally (1).

154. Tibia, form of distal end: unexpanded and rounded (0); transversely expanded and subrectangular (1).

155. Tibia, form of posteromedial corner in distal view: smoothly rounded (0); squared off, forming a right or obtuse angle, due to presence of posterolateral flange (1).

156. Fibula, width of distal end compared to proximal end: slightly narrower (0); equal to or greater (1); much narrower, fibula tapering distally, with distal end width less than 50% proximal end width (2).

157. Fibula, form of anterior trochanter: absent or low crest (0); large rugosity (1).

158. Astragalus and calcaneum, fusion: absent (0); coossified together with other crurotarsal elements (1); coossified and other crurotarsal elements free (2).

159. Astragalus and calcaneum, form of articulation: flat (0); concavoconvex, with concavity on calcaneum (1); concavoconvex, with concavity on astragalus (2).

160. Astragalus, anterolateral process, orientation of contact with calcaneum: ventral, astragalus overlaps calcaneum (0); lateral, astragalus abuts calcaneum (1).

161. Astragalus, size of ventral astragalocalcaneal articular facet: smaller (0) or equal or greater (1) than dorsal facet.

162. Astragalus, anterior ascending process: absent (0); present but small and anterolaterally located (1); present and pyramid-shaped, anteriorly located, and articulating with a flat descending process of the tibia (2).

163. Astragalus, posterior ascending process: absent (0); present (1).

164. Astragalus, form of articular facet for tibia: simple concave structure (0); flexed (1).

165. Astragalus, extent of articular facet for fibula: occupies more (0) or less than (1) 20% of the transverse width of the bone.

166. Astragalus, form of anteromedial corner: squared off or rounded (0); prominent and offset, forms acute angle (1).

167. Astragalus, form of posterior margin: excavated, with concave non-articular surface (0); straight or slightly convex (1).

168. Astragalus, groove on posterior surface: present (0); absent (1).

169. Calcaneum, transverse width of distal articular surface: greater than (0) or less than (1) 35% that of astragalus.

170. Calcaneum, form of fibular facet: gently convex (0); hemicylindrical "pulley" (1); concave or flat (2).

171. Calcaneum, tuber: present and large (0); rudimentary or absent (1).

172. Calcaneum, tuber, proportions: deeper than wide (0); wider than deep (1); tuber absent (2).

173. Calcaneum, tuber, form of distal end: unexpanded (0); flared (1); tuber absent (2).

174. Calcaneum, tuber, dorsoventrally aligned median depression on distal end: absent (0); present (1); tuber absent (2).

175. Distal tarsal 4, transverse width: greater (0) or subequal (1) to width of distal tarsal 3.

176. Distal tarsal 4, form in proximal view: ornamented by raised ridge (0); flat or convex (1).

177. Distal tarsal 4, size of articular surface for metatarsal V: occupies nearly entire lateral surface (0); limited to half or less lateral surface (1).

178. Metatarsus, form: broad weight-bearing structure, with metatarsals II-IV less than four times as long as broad (0); elongated, with metatarsals II-IV greater than four times as broad (1).

179. Metatarsus, configuration: metatarsals divergent from ankle, shafts of individual elements not in close contact (0); compact, with metatarsals I-IV tightly bunched (1).

180. Metatarsal I, length: less than (0) or greater than (1) 85% length of metatarsal III.

181. Metatarsal I, midshaft diameter: equal to or greater (0) or less than (1) midshaft diameters of metatarsals II-IV.

182. Metatarsal II, length: shorter (0) or equal to or longer (1) than metatarsal IV.

183. Metatarsal III, length: less than (0) or greater than (1) 40% length of tibia.

184. Metatarsal IV, form of distal end: sigmoidally curved lateral to shaft (0); straight and in line with shaft (1).

185. Metatarsal V, midshaft diameter: equal to or greater (0) or less (1) than midshaft diameter of metatarsals II-IV.

186. Metatarsal V, form of articular surface for distal tarsal 4: angled relative to shaft, resulting in a laterally divergent metatarsal V with a hooked proximal end (0); parallel to shaft, resulting in an unhooked metatarsal V that is parallel to or deflected behind the remaining metatarsals (1).

187. Pedal unguals, shape: mediolaterally compressed (0); dorsoventrally compressed (1).

B) PTEROSAUR AUTAPOMORPHIES AND IN-GROUP CHARACTERS

Sereno 1991 (autapomorphies); Kellner 2003 (ingroup)

188. External naris, location relative to posterior end of premaxillary tooth row (or homologous region if edentulous): anterior (0); posterior (1).

189. Premaxilla, dorsal ascending process, extent and contacts: extends only slightly posterior to external naris and contacts nasal (0); extends far posterior to external naris and contacts frontal (1).

190. Maxilla, extent of contribution to external naris: absent or limited to less than one third of the border (0); present and greater than one third of the border (1).

191. Maxilla, external antorbital fossa: present (0); absent (1).

192. Squamosal, contract with quadratojual: present (0); absent (1).

193. Squamosal, otic notch: present (0); absent (1).

194. Lower jaw, external mandibular fenestra: present (0); absent (1).

195. Long bones, internal structure: solid or slightly hollowed (0); extensively hollowed (1).

196. Coracoid, shape: plate-shaped (0); strut-like (1).

197. Scapula and coracoid, glenoid, orientation: primarily ventrally (0); laterally (1).

198. Sternum, shape: plate-like (0); arched with ventral spine or keel (1).

199. Pteroid bone: absent (0); present (1).

200. Cervical vertebrae, length of posterior centra (6-9): less (0) or greater (1) than length of middorsal centra (1).

201. Caudal vertebrae, length of middle and distal centra: less than (0) or greater than (1) five times height.

202. Caudal vertebrae, middle and distal elements, zygapophyses and haemal arches small (0) or extended as narrow intertwining rods (1).

203. Coracoid, foramen: present (0); absent (1).

204. Humerus, proximal articular surface, shape: convex (0); saddle-shaped (1).

205. Humerus, deltopectoral crest, dorsal margin: straight or convex (0); concave (1).

206. Metacarpal I, length relative to metacarpals II and III: much shorter (0); subequal (1).

207. Manus, penultimate phalanges: short, subequal to other phalanges of same digit (0); elongate, longer than other phalanges (1).

208. Pubis and ischium, contact: unfused (0); fused (1).

209. Prepubis (paired midline element anterior to pubis): absent (0); present (1).

210. Femoral head, form: confluent with shaft (0); offset from shaft by constriction distal to head (1).

211. Fibula, form of articulation with tibia dorsally: unfused (0); fused, elements form a tibiofibularis in which the fibula is splint-like and reduced (1).

212. Pes, individual phalanges of pedal digit V, length: phalanges absent (0); less than (1) or greater than (2) length of metatarsal V.

213. Skull, region anterior to external nares: reduced (0); elongated (1). Kellner 2003:3

214. Skull, naris and antorbital fenestra: separated (0); confluent (1). Kellner 2003:8

215. Dentary, anterior tip, orientation: dorsoventral (0); downturned (1). Kellner 2003:31

216. Teeth, multiple cusps: absent (0); present (1); teeth absent (2). Kellner 2003:38

217. Coracoid, contact with sternum: absent (0); present, surface flat and lacking posterior expansion (1). Kellner 2003:52

218. Humerus, length relative to metacarpal IV: greater than 2.50 (0); between 1.50 and 2.50. (1). Kellner 2003:54

219. Humerus, length relative to the femur: less than 0.8 (0); between 1.4 and 0.8 (1). Kellner 2003:55

220. Ulna, length relative to metacarpal IV: greater than 3.6 (0); between 3.6 and 2 (1). Kellner 2003:61.

221. Radius and ulna, diameter: subequal (0); diameter of radius approximately half that of the ulna or less (1). Kellner 2003:62.

222. Femur, length relative to metacarpal IV: more than 2.0 (0); between 1.0 and 2.0 (1). Kellner 2003:71

C) PHYTOSAUR AUTAPOMORPHIES AND IN-GROUP CHARACTERS

Sereno 1991 (autapomorphies); Hungerbuhler 2002 (ingroup)

223. Occiput, mediolateral width: less than (0) or greater than (1) twice dorsoventral height.

224. Piscivorous snout: absent (0); present (1). “Piscivorous snout” is a descriptive term for a set of correlated characters described by Sereno (1991:16) that together constitute an autapomorphy of Phytosauria.

225. External naris and orbit, orientation: primarily lateral (0); primarily dorsal (1).

226. Quadratojugal, shape: L-shaped (0); subtriangular (1); hatchet shaped (2).

227. Nasal, anterior extent: posterior (0) or anterior (1) to external naris.

228. Paramedian “septomaxilla”: absent (0); present (1).

229. Maxilla, contribution to internal naris: present (0); absent, excluded by palatine-premaxilla contact (1).

230. Palate, postpalatine fenestra: large (0); small, slit-like, nearly absent (1).

231. Interclavicle: absent (0); small (1); large, subequal to scapulocoracoid in length and maximum width, longer than long bones except femur (2).

232. Length of snout (ratio of pre-orbital to orbital plus postorbital length): less than 1 (0); 1-3 (1); 3-3.5 (2); exceeds 3.5 (3). Hungerbuhler 2002:1

233. Suture between maxilla, premaxilla, and nasal, morphology: slopes anteroventrally (0); dorsally convex lobe (1). Hungerbuhler 2002:2

234. Maxilla, lateral extent (in dorsal view): alveolar rim laterally convex or straight (0); laterally concave (1). Hungerbuhler 2002:4

235. Dentition, degree of heterodonty: homodont (0); bipartite upper dentition (1); tripartite upper dentition (2). Hungerbuhler 2002:5

236. Septomaxilla, anterior extent: septomaxilla absent (0); anterior to (1) posterior to or at level with (2) anterior tip of nasal. Hungerbuhler 2002:6

237. Nasal, contribution to internasal septum: contributes (0); excluded by septomaxilla (1). Hungerbuhler 2002:8

238. External nares, elevation: dorsal rim below or at level of skull roof, or slightly raised (“roman nose” of some rauisuchians) (0); raised substantially above level of skull roof (1). Hungerbuhler 2002:9

239. External nares, position: terminal (0); non-terminal, posterior rim of nares in front of anterior rim of antorbital fenestra (1); non-terminal, posterior rim of nares behind anterior rim of antorbital fenestra (2). Hungerbuhler 2002:10

240. Infranasal recess: absent (0); present (1). Hungerbuhler 2002:11

241. Interorbitonasal area, topography: flat (0); convex (1). Hungerbuhler 2002:14

242. Pre-orbital depression: absent (0); present (1). Hungerbuhler 2002:15

243. Postorbital-jugal bar, depression: absent (0); present (1). Hungerbuhler 2002:16

244. Skull roof sculpture: smooth or equally divided between raised areas and pits (0); concave pits predominate (1). Hungerbuhler 2002:17

245. Pre-infratemporal shelf: absent (0); present (1). Hungerbuhler 2002:18

246. Postorbital-squamosal bar, medial lamella: absent (0); present and narrow (1); present and moderately developed, supratemporal fenestra closed to half of original width (2); present and strongly developed, supratemporal fenestra reduced to slit (3); present, lamella merges with parietal, supratemporal fenestra oblitered in dorsal view (4). Hungerbuhler 2002:19

247. Supratemporal fenestra, position of anterior border: at level of skull roof (0); raised above skull roof (1). Hungerbuhler 2002:20

248. Parietals, degree of overhang over supraoccipital shelf: none (0); medial parts of squamosal processes of parietals overhang supraoccipital shelf (1); deep central ledge (2). Hungerbuhler 2002:21

249. Postorbital-squamosal bar, cross section of posterior half, shape: low, dorsoventrally compressed (0); high, triangular (1). Hungerbuhler 2002:22

250. Parietal-squamosal bar, depression, depth: absent, bar at level of skull roof (0); moderate, bar depressed for 15-25 percent of absolute skull height (1); strong, bar depressed for more than 25 percent of absolute skull height (2). Hungerbuhler 2002:23

251. Parietal-supraoccipital complex, morphology of dorsal region formed by squamosal processes of the parietals, shape: angular (0); round (1); subrectangular (2). Hungerbuhler 2002:24

252. Parietal, posteriorly projected prongs: absent (0); present (1). Hungerbuhler 2002:25

253. Parietal-squamosal bar, dorsal edge, orientation: horizontal (0); gently sloping (1); steeply sloping (2); entirely or in parts vertical (3). Hungerbuhler 2002:26

254. Postorbital-squamosal bar, lateral ridge: absent (0); present and blunt (1); present and sharp, forming overhang (2). Hungerbuhler 2002:27

255. Infratemporal fenestra, ridge on dorsal rim: absent (0); present (1). Hungerbuhler 2002:28

256. Squamosal, medial rim along supratemporal fenestra, orientation: straight (0); angular (1); sinuous (2).

257. Squamosal, medial extent: to midlength of parietal-squamosal bar (0); enters base of supraoccipital shelf wedged between parietal and supraoccipital (1); enters rim of supraoccipital shelf dorsal to parietal (2). Hungerbuhler 2002:30

258. Squamosal, posterior process, length: absent (0); short, maximum c. 10 mm (in phytosaurs) (1); moderate, ratio of postorbital length to length of process exceeds 4.5

(2); long, ratio of postorbital length to length of process less than 4.5 (3). Hungerbuhler 2002:31

259. Squamosal, extremity of element, dorsoventral expansion, form: dorsoventrally compressed (0); dorsoventrally thickened (1); dorsoventrally strongly thickened, dorsal surface of squamosal is raised terminally (2). Hungerbuhler 2002:32

260. Squamosal, extremity of element, mediolateral expansion, form: tip of squamosal tapering (0); tip transversely wide or expanded, may result in a distinct terminal knob of the squamosal (1). Hungerbuhler 2002:33

261. Squamosal, lateral flange: absent (0); present (1). Hungerbuhler 2002:34

262. Squamosal, subsidiary opisthotic process: absent (0); present (1). Hungerbuhler 2002:35

263. Supraocciptal shelf, depth and shape: shallow, longitudinal axis of shelf vertical (0); deep, axis of shelf straight and horizontal (1); deep, axis of shelf with steep slope anteriorly and terminal horizontal deflection of shelf (2). Hungerbuhler 2002:36

264. Parietal-squamosal bar, medial half, form: high and thin (0); low, continuously thin (1); low, basally thickened (2). Hungerbuhler 2002:37

265. Posttemporal fenestra, lateral border, form: delimited by the contact of the parietal process of the squamosal (dorsal border) and the paroccipital process (ventral border) (0); delimited laterally by a thin, vertical lamina of the squamosal below the parietal process (1); lamina of the squamosal extends onto the paroccipital process, forming the ventrolateral border of posttemporal fenestra (2). Hungerbuhler 2002:38

266. Exoccipital and supraoccipital shelf, anteroposterior length: short (0); broad, overhangs foramen magnum and occipital condyle (1). Hungerbuhler 2002:39

267. Supraoccipital, ventral rim, participation in posttemporal fenestra: present (0); absent (1). Hungerbuhler 2002:40

268. Posttemporal fenestra, dimensions: transversely moderately wide, dorsoventrally high, less than three times wider than high (0); transversely wide, dorsoventrally low, about six times wider than high (1); transversely short, dorsoventrally very low, oval or slit-like (2); extremely reduced (3). Hungerbuhler 2002:41

269. Quadrate foramen, size: large (0); significantly reduced or absent (1). Hungerbuhler 2002:42

270. Interpremaxillary fossa, shape: absent (0); present, broad and rounded (1); present, narrow slit (2). Hungerbuhler 2002:43

271. Palatine, anterior extent: tip located behind the posterior rim of the choana (0); tip extends forward beyond the posterior rim of choana (1); tip extends forward beyond the anterior rim of choana (2). Hungerbuhler 2002:44

272. Palatine, lateral extent: not visible on palatal vault in ventral view (0); extends onto palatal vault and meet along the midline (1). Hungerbuhler 2002:45

273. Suborbital fenestra, shape: elongate, wide (0); elongate, slit-like (1); reduced to a singular oval fenestra, or subdivided into two or more small openings (2). Hungerbuhler 2002:46

D) AETOSAUR AUTAPOMORPHIES AND IN-GROUP CHARACTERS

Parker 2007 (autapomorphies and ingroup)

274. Premaxilla, anterior end, anteroventrally inclined, mediolaterally expanded, edentulous ‘shovel-shaped’ snout: absent (0); present (1). Parker 2007:1

275. Teeth, morphology (for those taxa with heterodont dentition, refers to teeth at front of jaws): teeth absent (0); mediolaterally compressed and recurved (1); bulbous and conical with recurved tips (2); bulbous and conical but lacking recurved tips (3); leaf-shaped (4). Parker 2007:2

276. Jugal, orientation: not downturned (0); downturned (1). Parker 2007:7

277. Mandible, overall slipper shape: absent (0); present (1). Parker 2007:8

278. Dentary, number of teeth: nine or more (0); fewer than nine (1); teeth absent (2). Parker 2007:9

279. Presacral vertebrae, neural spines, height: high (0); generally low, less than height of centrum (1). Parker 2007:11

280. Cervical vertebrae, centra, ventral keel: present (0); absent (1). Parker 2007:12

281. Dorsal and lateral plates, anterior bars, morphology: plates absent (0); absent (1); weakly raised (2); strongly raised (3). Parker 2007:13

282. Cervical dorsal paramedian plates, shape: plates absent (0); wider than long (1); longer than wide (2). Parker 2007:15

283. Paramedian plates, patterning form: plates absent (0); radiate (1); random (2); smooth (3). Parker 2007:16

284. Paramedian plates, posterior margin, contacted by dorsal eminence: plates absent (0); dorsal eminence absent (1); majority of the time (2); or never (3). Parker 2007:18

285. Cervical and anteriormost paramedian plates, raised dorsal eminence: plates absent (0); absent (1); present (2) Parker 2007:19

286. Cervical paramedian plates, morphology, dorsoventrally thickened with tongue-and-groove articulations: plates absent (0); no (1); yes (2). Parker 2007:21

287. Lateral cervical armor, spikes and horns: absent (0); present and short (1); present and extremely elongate (2). Parker 2007:22

288. Paramedian plates, flexure: plates absent (0); none or minimal (1); strongly flexed ventrally (2). Parker 2007:23

289. Lateral plates, minimum angle of flexion between the dorsal and lateral flanges: plates absent (0); obtuse (1); approximately perpendicular (2); strongly acute (3). Parker 2007:24

290. Middorsal lateral plates, symmetry of dorsal and lateral flanges: plates absent (0); symmetrical (1); asymmetrical with dorsal flange longest (2); asymmetrical with lateral flange longest (3). Parker 2007:25

291. Carapace, narrow region (‘waist’) anterior to sacrum: carapace absent (0); present (1); absent (2). Parker 2007:26

292. Pelvic and anterior caudal lateral plates, shape: plates absent (0); roughly equant in width and length and possessing a sharp medially situated keel (1); roughly triangular in lateral view with a semicircular ventrolateral border and a hook-like eminence (2); rectangular and ventral to a well-developed spine (3). Parker 2007:28

293. Paramedian plates, dorsal eminence, location: plates absent (0); dorsal eminence absent (1); centralized (2); moderately offset medially (3); strongly offset medially (4). Parker 2007:29

294. Anterior and middorsal armor, lateral spikes, morphology: absent (0); dorsoventrally flattened horn (1); conical spine (2). Parker 2007:30

295. Ventral plate rows, number: plates absent (0); 10 or more (1); less than 10 (2). Parker 2007:31

296. Cervical lateral plates of the sixth row, size: plates absent (0); small (1); extremely enlarged (2). Parker 2007:35

297. Anterior dorsal lateral plates, mound-like dorsal eminences: plates absent (0); absent (1); present (2). Parker 2007:37

E) ORNITHOSUCHID AUTAPOMORPHIES Sereno 1991 (autapomorphies)

298. Upper jaw, arched diastema: absent (0); present (1); present with two teeth inset (2). Sereno 1991:15 ADDED SECOND DERIVED STATE FOR COELOPHYSOIDS

299. Palate, accessory palatine-pterygoid fenestra: absent (0); present (1). Sereno 1991:17

300. Lower jaw, symphysis, length and participating elements: short, restricted to dentary (0); long, approximately 30 percent of jaw length, splenial participates (1); extremely long (correlated with elongate snout), splenial participates (2). Sereno 1991:18

F) CROCODYLOMORPH AUTAPOMORPHIES AND IN GROUP CHARACTERS Clark et al. 2004 (autapomorphies and in group)

301. Prefrontal, descending process, extent: does not (0) or does (1) contact palate. Clark et al. 2004:6

302. Exoccipitals, contact of opposing elements: absent, exoccipitals separated dorsal to foramen magnum (0); absent, approaching midline without contacting (1); present, contacting below supraoccipital (2). Clark et al. 2004:20

303. Prootic, contact with paroccipital process: present, broadly contacts anterior surface of process (0); absent, not in broad contact (1). Clark et al. 2004:21

304. Braincase, basipterygoid processes, shape and excavation: simple, without large cavity (0); greatly expanded, with large cavity (1). Clark et al. 2004:26

305. Articular, dorsomedial projection posterior to glenoid fossa: absent (0); present (1). Clark et al. 2004:27

306. Maxillary and posterior dentary teeth, distal edges: concave or straight (0); distinctly convex (1); teeth absent (2). Clark et al. 2004:28

307. Metacarpals, proximal ends, articulation: overlapping (0); abutting each other without overlapping (1). Clark et al. 2004:30

308. Paramedian dorsal osteoderms, anterior process on anterior edge: osteoderms absent (0); absent, edge straight (1); present (2) Clark et al. 2004:33

309. Paramedian dorsal osteoderms, topography: osteroderms absent (0); flat (1); with distinct longitudinal bend near lateral edge (2). Clark et al. 2004:34

G) ORNITHISCHIAN AUTAPOMORPHIES AND IN GROUP CHARACTERS

Butler et al. 2007 (autapomorphies and in group)

310. Premaxilla, posterolateral process, contact with lacrimal: absent (0); present, excludes maxilla-nasal contact (1). Butler et al. 2007:3

311. Premaxilla, ventral margin, position: level with (0) or offset ventrally relative to (1) the ventral margin of the maxilla. Butler et al. 2007:4

312. Premaxilla and maxilla, diastema: absent (0); present (1). Butler et al. 2007:5

313. Premaxilla and maxilla, diastema, form: diastema absent (0); straight or arched, not recessed (1); arched and recessed (2). Butler et al. 2007:6

314. Nasals, single deep elliptical fossa present along sutural line of the nasals: absent (0); present (1). Butler et al. 2007:10

315. Internal antorbital fenestra, anteroposterior length: large, at least 15% of the skull length (0); strongly reduced (1). Butler et al. 2007:12

316. Antorbital fossa, secondary openings (in addition to internal antorbital fenestra) positioned anteriorly within fossa: absent (0); present (1). Butler et al. 2007:14

317. Maxilla, buccal emargination: absent (0); present and weak (1); present and well-developed (2). Butler et al. 2007:15, 16

318. Orbital region, accessory ossification (palpebral/supraorital): absent (0); present (1). Butler et al. 2007:17

319. Jugal, boss: absent (0); present (1). Butler et al. 2007:24

320. Jugal-postorbital joint, form: elongate scarf joint (0); short butt joint (1). Butler et al. 2007:28

321. Quadrate, ventral condyles, size: subequal (0); medial condyle larger (1); lateral condyle larger (2). Butler et al. 2007:36

322. Posttemporal foramen, position: forms a notch in the dorsal margin of the exoccipital-opisthotic and enclosed dorsally by the squamosal or parietal (0); entirely enclosed within the exoccipital-opisthotic (1). Butler et al. 2007:48

323. Predentary: absent (0); present (1). Butler et al. 2007:51

324. Posterior premaxillary teeth, occlusion: teeth absent (0); oppose dentary teeth (1); oppose predentary only (2). Butler et al. 2007:53

325. Dentary, symphysis, shape and extent: V-shaped, restricted to the anterior margin of the dentary (0); spout shaped, expanded along the ventral border of the dentary (1). Butler et al. 2007:56

326. Dentary, marked lateral ridge in posterior portion that demarcates an emargination forming half of the transverse width of the bone: absent (0); present (1). Butler et al. 2007:57

327. Lower jaw, coronoid process: absent (0); weak, depth of mandible at coronoid is less than 140% depth of mandible beneath tooth row (1); well-developed, distinctly-elevated, depth of mandible at coronoid is more than 18% of mandible beneath tooth row (2). Butler et al. 2007:60,61

328. Jaw joint, level relative to maxillary tooth row: level, not offset ventrally (0); offset ventrally (1). Butler et al. 2007:67

329. Premaxillary teeth, number: six (0); five (1); four (2); three (3); two (4); zero (5); 7+ (6). Butler et al. 2007:68, extra state added for phytosaurs

330. Premaxillary teeth, size: teeth absent (0); all teeth subequal in size (1); posterior premaxillary teeth significantly larger (2). Butler et al. 2007:70

331. Maxillary and dentary crowns, shape: teeth absent (0); apicobasally tall, blade-like (1); apicobasally short and triangular (2); chisel-shaped, denticles restricted to apical third of crown (3). Butler et al. 2007:71

332. Maxillary and dentary crowns, marginal ornamentations, form: teeth absent (0); no serrations or fine serrations set at right angles to the margin of the tooth (1); coarse serrations (denticles) angle upwards at 45 degrees from the margin of the tooth (2). Butler et al. 2007:72

333. Maxillary and dentary crowns, apicobasally extending ridges on lingual and labial surfaces: teeth absent (0); absent (1); present (2). Butler et al. 2007:73

334. Maxillary teeth, prominent primary ridge on labial side: teeth absent (0); absent (1); present (2). Butler et al. 2007:75

335. Dentary teeth, prominent primary ridge on lingual side: teeth absent (0); absent (1); present (2). Butler et al. 2007:76

336. Maxillary and dentary crowns, labiolingual expansion of crown (cingulum): teeth absent (0); absent (1); present (2). 25. Butler et al. 2007:78

337. Dentary, dentition, heterodonty: teeth absent (0); absent, all teeth nearly identical (1); single enlarged caniform anterior dentary tooth, crown not mesiodistally expanded above root (2); multiple enlarged teeth at front of jaw (3). Butler et al. 2007:79, extra state added for pterosaurs

338. Maxillary and dentary tooth rows, overlap of adjacent crowns: teeth absent (0); absent (1); present (2). Butler et al. 2007:82

339. Maxillary and dentary teeth, crown and root, form: teeth absent (0); confluent (1); crown mesiodistally expanded above root (2). Butler et al. 2007:83

340. Maxillary and dentary teeth, position of maximum abicobasal crown height: teeth absent (0); anterior portion of tooth rows (1); central portion of tooth rows (2). Butler et al. 2007:84

341. Manus, longest manual phalanx as percentage of length of humerus: less than 10% (0); more than 15% (1). Butler et al. 2007:100

342. Metacarpals, block-like proximal ends: absent (0); present (1). Butler et al. 2007:101

343. Manus, extensor pits on dorsal surface of the distal end of phalanges and metacarpals, form: absent or poorly developed (0); deep and well-developed (1). Butler et al. 2007:103

344. Manus, unguals, recurvature and flexor tubercle: weakly recurved and tubercle absent (0); strongly recurved and tubercle present (1). Butler et al. 2007:104

345. Ilium, brevis shelf and fossa, orientation: fossa absent (0); fossa faces ventrolaterally and is visible in lateral view along its entire length, creating a deep postacetabular portion (1); fossa faces ventrally and posterior portion cannot be seen in lateral view, forming at least a narrow horizontal shelf (2). Butler et al. 2007:110

346. Ischium, dorsal groove: absent (0); present (1). Butler et al. 2007:117

347. Pubis, orientation: anteroventral (0); rotated posteroventrally to lie alongside the ischium (opisthopubic) (1). Butler et al. 2007:120

348. Pubis, prepubic process: absent (0); present (1). Butler et al. 2007:124

349. Pubis, symphysis, extent: elongate (0); restricted to distal end of blade or absent (1). Butler et al. 2007:128

350. Lesser trochanter, level of most proximal point: trochanter absent (0); positioned distally on shaft, separated from greater trochanter by deep notch visible in medial view (1); positioned proximally, approaches level of proximal surface of femoral head, closely appressed to greater trochanter, no notch visible in medial view (2). Butler et al. 2007:133

351. Fourth trochanter, pendant: trochanter absent (0); no (1); yes (2). Butler et al. 2007:134

352. Tibia maximum expansion of distal end: considerably less (0) or subequal (1) to that of proximal tibia (1). Butler et al. 2007:137

353. Tibia, distal end, form: subquadrate, posterolateral process not substantially developed (0); elongate caudolateral process backs fibula (1). Butler et al. 2007:138

354. Pes, digit 1, metatarsal I form: robust and well-developed, distal end of phalanx I-1 projects beyond the distal end of metatarsal II (0); metatarsal I reduced and proximally splint like end of phalanx I-1 does not extend beyond the end of metatarsal II (1). Butler et al. 2007:143

355. Metatarsal II, proximal end, anteroposterior expansion: less than (0) or greater than (1) expansion of metatarsal III (1). Butler et al. 2007:144

356. Metatarsal V, length: less than 50% (0) or less than 25% (1) of length of metatarsal II (1). Butler et al. 2007:145

357. Epaxial ossified tendons: absent (0); present (1). Butler et al. 2007:147

H) SAURISCHIAN AUTAPOMORPHIES AND IN GROUP CHARACTERS (SAUROPODOMORPHA, THEROPODA, NEOTHEROPODA) Sereno 1999 (autapomorphies and in group)

358. Subnarial foramen: absent (0); present (1). Sereno 1999:62

359. Jugal-lacrimal articular relation: lacrimal overlaps jugal (0); jugal overlaps lacrimal (1). Sereno 1999:63

360. Jugal, posterior process, shape: tapered (0); forked (1). Sereno 1999:64

361. Cervical ribs, middle elements, form and inclination: posteroventrally inclined (0); long, parallel to cervical column (1). Sereno 1999:67

362. Distal carpal 5: present (0); absent (1). Sereno 1999:68

363. Manus, length (measured along digit II or III, whichever is longest): 20-30% (0); approximately 40% (1); or 50-70% (2) of length of humerus + radius. Sereno 1999:69

364. Manual digit I, phalanx I length: shorter (0) or equal to or longer (1) than metacarpal I. Sereno 1999:70

365. Astragalus, ascending process, shape: process absent (0); small wedge (1); quadrangular (2). Sereno 1999:71

366. Metatarsals II-IV, form of basal articulation: nonoverlapping (0); overlapping II on III on IV (1). Sereno 1999:72

367. External naris, size: small (0); large (1). Sereno 1999:73

368. Narial fossa, ventral width: narrow, above subnarial foramen when present (0); deep, including subnarial foramen when present (1). Sereno 1999:75

369. Premaxilla, posterolateral process, articulation: lateral aspect of snout (0); dorsal aspect of maxillary anteromedial process (1). Sereno 1999:76

370. Maxilla, anterior maxillary foramen: absent (0); present (1). Sereno 1999:77

371. Maxilla, antorbital fossa, posterior portion of medial wall: present (0): absent (1). Sereno 1999:78

372. Supra-jugular foramen: absent (0); present (1). Sereno 1999:79

373. Proximal carpals (and distal carpal 4): present (0); very reduced or absent (1). Sereno 1999:80

374. Ilium, pubic peduncle length: less (0) or more (1) than twice the distal width of the peduncle. Sereno 1999:81

375. Ilium, pubic peduncle, orientation of main axis: straight (0); arched (1). Sereno 1999:82

376. Astragalus, fibular facet, orientation: dorsolateral (0); lateral (1). Sereno 1999:84

377. Pedal digit I, ungual length: shorter (0) or longer (1) than other pedal phalanges. Sereno 1999:85

378. Ectopterygoid, fossa: absent (0); present (1). Sereno 1999:87

379. Lower jaw, intramandibular joint: absent (0); present (1). Sereno 1999:88

380. Cervical vertebrae, epipophyses, shape: absent (0); crest or rugosity (1); prong-shaped process (2). Sereno 1999:89

381. Metacarpals I-III, intermetacarpal articular facets: absent (0); present (1). Sereno 1999:91

382. Axial intercentrum, width: less than (0) or greater than (1) maximum width of axial centrum. Sereno 1999:96

383. Caudal vertebrae, distal elements, prezygapophyses, length: short (0); elongate (1). Sereno 1999:97

384. Scapula, blade, length: less (0) or more (1) than three times distal width. Sereno 1999:98

385. Metacarpals IV and V, diameter: short (0); vestigial, less than 50% diameter of metacarpal III or metacarpal II (1). Sereno 1999:100

386. Femur, distal end: anterior attachment depression: absent (0); present (1). Sereno 1999:102

387. Intramandibular joint, form: absent (0); splenial convex (1); splenial concave (2). Sereno 1999:103

388. Femur, proximal shaft, anterolateral margin, form: rounded (0); crested (1). Sereno 1999:104

389. Palate, teeth: present (0); absent (1). Sereno 1999:107

390. Premaxilla, medial foramen: absent (0); present (1). Sereno 1999:109

391. Nasal, posterolateral process: absent (0); present (1). Sereno 1999:110

392. Antorbital fossa, size: small or moderate, anteroposteror diameter may be greater than the anteroposterior diameter of other skull openings (0); large, anteroposterior diameter greater than any diameter of other skull openings (1). Sereno 1999:111

393. Maxilla, promaxillary fenestra and antrum: absent (0); present (1). Sereno 1999:112

394. Lacrimal, crest with pneumatic excavation: absent (0); present (1). Sereno 1999:113

395. Lacrimal, ventral process with flange: absent (0); present (1). Sereno 1999:114

396. Squamosal, anterior process, orientation in lateral view: anterior (0); anterodorsal (1). Sereno 1999:115

397. Palatine, anterior process shape: tapered distally (0); expanded distally (1). Sereno 1999:116

398. Axis, prezygapophyses, shape: low process (0); cylindrical process (1). Sereno 1999:123

399. Axis, intercentrum, length: 25% (0) or 50% (1) axial centrum length. Sereno 1999:126

400. Caudosacral ribs, attachment position on postacetabular process: along ventral margin (0); rises to a posterodorsal corner (1). Sereno 1999:128

401. Distal carpal I, distal articulation: metacarpal I (0); metacarpals I and II (1); distal carpal I absent (2). Sereno 1999:130

402. Manual digits and metacarpals, longest: digit III, metacarpal III (0); digit II, metacarpal II (1); digit IV (2). Sereno 1999:131

403. Manual digit V: present (0); absent (1). Sereno 1999:132

404. Metacarpal I, length: longer (0) or shorter (1) than phalanx 1 or ungual of digit I (1). Sereno 1999:133

405. Metatarsal I, length: more (0) or less (1) than 50% metatarsal II length. Sereno 1999:142

406. Metatarsal I, location of articulation on metatarsal II: medial side of proximal end (0); posteromedial side halfway down the shaft (1). Sereno 1999:143

407. Metatarsal V, shaft width: robust (0); slender (1). Sereno 1999:146

I) ADDITIONAL SAURISCHIAN IN GROUP CHARACTERS (SAUROPODOMORPH STEM, SAUROPODA, COELOPHYSOIDEA) Sereno 1999

408. Premaxilla, beak: absent (0); present (1). Sereno 1999:1

409. Maxillary vascular foramina, arrangement: irregular (0); one directed posterior, five-six directed anterior (1). Sereno 1999:4

410. Squamosal ventral process, shape: tab-shaped (0); strap-shaped (1); process absent (2). Sereno 1999:5

411. Axis, postzygapophyses, length: overhang centrum (0); flush with posterior centrum face (1). Sereno 1999:7

412. Humerus, deltopectoral crest, deflection: 45-60 degrees (0) or 90 degrees (1) to the transverse axis of the distal condyles. Sereno 1999:9

413. Distal carpal 1, size: small (0); large (1); absent (2). Sereno 1999:10

414. Metacarpal I, basal articulation: flush with other metacarpals (0); inset into the carpus (1). Sereno 1999:11

415. Metacarpal I, basal width: less than 50% (0) or more than 65% (1) maximum length. Sereno 1999:12

416.Manual digit I, phalanx 1, proximal heel: absent (0); present (1). Sereno 1999:13

417. Manual digit I-phalanx 1, rotation of axis through distal condyles: rotated slightly ventromedially (0); rotated 45-60 degrees ventrolaterally (1). Sereno 1999:14

418. Ilium, preacetabular process, shape: blade-shaped (0); subtriangular (1). Sereno 1999:15

419. Ischium, distal shaft, cross section: ovate (0); subtriangular (1). Sereno 1999:17

420. Metatarsal II, proximal articular surface, shape: subtriangular or subquadrate (0); hourglass-shaped (1). Sereno 1999:18

421. Metatarsal IV, proximal end, transverse width: subequal (0) or three times broader than (1) dorsoventral depth. Sereno 1999:19

422. Nasal, anteroventral process, basal width: subequal to (0) or 50% broader than (1) anterior process width. Sereno 1999:21

423. Prefrontal, posterior process, size: small (0); large (1). Sereno 1999:23

424. Braincase, basipterygoid processes, deep septum between processes: absent (0); present (1). Sereno 1999:29

425. Nasal, participation in secondary antorbital fossa wall: absent (0); present (1). Sereno 1999:30

426. Posture, columnar orientation of limbs: absent (0); present (1). Sereno 1999:1

427. Humerus, deltopectoral attachment, development: prominent (0); reduced to a low crest or ridge (1). Sereno 1999:3

428. Ulna, olecranon process, development: prominent, projecting above proximal articulation (0); reduced to a low crest or ridge (1). Sereno 1999:4

429. Ulna, proximal condyle, shape: subtriangular (0); triradiate, with deep radial fossa (1). Sereno 1999:5

430. Femur, cross section, shape: round (0); elliptical, with long axis oriented mediolaterally (1). Sereno 1999:10

431. Skull length, less than (0) or more than (1) three times posterior skull height. Sereno 1999:33

432. Dentary, size of tooth three: subequal (0) or enlarged (1) relative to tooth two; teeth absent (2). Sereno 1999:38

433. Pubic foot, anteroposterior length: longer (0) or shorter (1) than ischial foot; pubic foot absent (2). Sereno 1999:41

434. Tibia, distal flange posterior to fibula: absent (0); lobe-shaped (1); tabular (2). Sereno 1999:42

435. Antorbital fossa, anterior end, position: posterior (0) or ventral (1) to posterior end of external naris. Sereno 1999:43

436. Antorbital fossa, ventral margin: smoothly confluent with main body of maxilla or slightly offset (0); offset by thin, sharp rim (1). Sereno 1999:44

437. Dorsal vertebrae, centrum length: subequal to (0) or more than 2.5 times (1) height of anterior centrum face. Sereno 1999:48

7) Data Matrix

Erythrosuchus
0001000000000210010101000000010000000010001000?00000000000000?00?000?
00100100000000000010000?001??00000??0011?00000200000000000000000000?0
00?00??000000?00?00001?00000100000000000?010000?0000010000?0000000?0
00010000001?00000000???1000000000000000000000000000000001100???0100
00???????0?0000?00000?00200000??0000000000000000000111111111112?00?000
000?10??000000???01000?0?0000?0000?00?0000?100000?0?0????00000000?01??1
0??0101001000000000

Euparkeria
000001001000021000000100000110010000000000000000000000000000000000000
000?0100000000010000000000000000000000?000002000000000000000000?0?0
000001000000?000??0000000000000000000000000000000001000000?0000000??
0000100000?0?00000000001100000000000000000000000003000000100300?0010
001012311201000010000000?000010022000000000001000?000211111111112?00?0
000001000?000000??001000?0??00000000000?0000?1000000000???000000100?00
0010??0000001?00000000

PROTEROCHAMPSIDAE
1000000000000000100000010000000000000200000000000000100000000100???0?????
0000000000000000000000000100000000000?000002000000000000000000?0???
?000000?000??00?00000000000000000000?00000010000
0001000000?00?00000?000000000000000?111000000110000001000000000000000002
03000000?0?0001??0100000123112010000100000002??00?2200000000001?0000
000111111111112????0000001001?000000???01000?0??0000000?0?000000?100000
0000????10000000?????10??00?0001001000000

Scleromochlus
101012?0100000?00000110000001??00000?0??01000???00?2????????????1??????01
????0000??00???2??00??0221000011000?000002001000001???00010000?0?????00
?1??100??01?0000??0?00?0?0?????1?01110111000000000??0000?0000?000?0000000
00000000?00?0000000000000000000000?10?00??????????????00??010001?00000
00000000000000?0???00?0000000000000??00?000?11111?1111100??0?00?00000?
000?00???00000?0??000??0?0?0100001?0000000?????0?10000??0?00??10??????00
1?01?00000

Eudimorphodon10001000100000010010?00000?0?0000?0?????00000???0??0??????
????????????01????01000??0000200000??22200001100012011002101000000000000
00000?0????0??010?10100?0?2010???0???????12221?011?01??00011111?1111111
11111111111210111111?1000000??0100?000100000000??????00??????????????0??
?010000?0000000000000000000??0???000000000??0000?0?01?00021111111311210
010000?001??0?00?01?100010??0?0000??000?110000??00000????021000000??01
000000??00?0000?0102?000

Peteinosaurus???
???????????????????00??10000???2220000110001 2???0???01??00???00?00000?????
?????????10?0?00?201????0???????12221?01110101000??????1111?1?1111111111
12???11111?0????????0????0???????????????????????????????????????1?000?00000

000000000000????????0000??????????????0??00???111?11?11?10010?00?001?0000
?????1000??????00000?0?0?110?00??????????????210000????0100000???????000?0
??????0

Preondactylus
10?0?0????0000?11010???000?0????00????????????????????????????????????00???
?0100???00?????00???2220000110001 2???0???????00???00?00??0???????????????1
?????0?201???????????????????1110111000 1111??1111?1111111111?11?110??110
?0?00?00??0100?00010000000???????00???????????????0???01000??000000000000
000000???????0000?000??0000???01000021111111311 21001??00?001?00?00??1?1
0?010??0?0?0?0?0?0?110?00???00????????2100000???01000000??0??0000?0102??
00

Austriadactylus
1000?0?01?0001?11010???000?0?00?0???????????00?000000?????????????????????
??????????????????00???222000011000?2??
?????????????????????????????11?????????11111111?11?10???????????10?11??????0
0?00??0100?000100000000??????00??10???????????0???01?00??0000000000000000
00???????0000?000??000????01?0001111111?1121001??????0?????00?0??1???10
??0????????????0???0????00000?????2?????0?0????????????0??0000?01???00?

Lagerpeton
???
??????00??0????01122?????????????0010020000001000101011001000 1?1000001?10
?0101020200?110?101121222101110101111 0???????0????????????00000?????????
??0?0000000000000000
0???????????00???????????????????????????????????????0000001001100???????10?????
??0000?????????0?0?????????????0????000??????????0000????0???0??20??0

Dromomeron
???
??10010001?000001 1111??1
010??20??1100101021222????????????????????0???????????????00?????????????????
??0000000000000000?????
?????00???0000????????????1???????????0??
???????0?0??0???0???0???

Marasuchus
?0?????????0???????00?1??????????????????????????????????????00021?1??????????
11200000000000?00122100001 10001?1010020000001200210010000010(1,2)?111
1000111?1001120000?1000101101000101110101111???0????000??010?0???00000
00?00??????0??????0?0???????????????????????????????0??0?????????1???0?0000000
00000000000????00?0?00?000??????????????????1111?1?111????0000011000?00??
?????10????00?000???0?000?0?0????0????000????100???0??????00????0?00??0??0
00?0

Pseudolagosuchus
???
??????????0??0????22??????????????????????????1?0?20???0000?0?1?111110??1??1
001120001?200010?101000?????????????????????0???????????????00??????????????

??0000000000000000???
???????00?????????????????????????????????????1100???0???????2??????????0
?????????0?0????????????????????????????????????0???0??20???

Silesaurus
00?001????0002100000010000?1??0000?????0?0????????0?001??00002001???010
000?11200000010200000002201001110000?10000200102012002001101001122?11
1110010211011000001?2000?11121??????010111111100000???000?0000000??0000
000000?0?0?000?000?0100000000??0??????????????????0??0?0?????0400000000
0000000000000000??0001?0000000?000001001000021222??11222????100001100
?0000??1???2000010??000???0???1?0?0???00????000?????0010?00?????00000?000
01000021000

Sacisaurus
?0????????0??????00011?????????????????????0?????????????????????????100???
??????????????0????22?1????????????0002000000220?200110100(0,1)12(1,2)?1?11
10??12110111??????2?????????????????????????????0???0?0???00?????0000?0000?
??????0????????0?0??????????????????????????????????????4?00??000000000000
000000?0?????1?00?000??00?????0100????2222211222????0?00?1100???0???????2
0????0??00???????11?0?0????0??????????????10????????0???????0???0?02100?

Eucoelophysis
??
??2?0020???01001?22?1110100??1???
???????????????????????????????0??????????000??????????0000?????0???????????
??0000000000000000??????
????00??????????????????????????????????????00?11?????0???????????????????????
?????0?0?????????????????????????????????????0???0??2????

Lewisuchus
???????0???????????0011?0?????????????????0?000?0?00001?0???0000?10?????00??
??1120000000?????0???22?1000??0000???????????????????????0001?????????1???0
???????????????????????????????1???0???0???0??0000?????000????0??00000?????0
0??????0?0?0???????0??0??0?????0??3????0??0??1??0??1000010000000000000000
000???00?0?00?0?0??00?00??01?000??1111111111????????????????0??01????0???
?0?????????0???0?0?0????0??0?00????????????0?????????????0?00??0?0???00

Eoraptor
0010010001000111000011?000?100000012???1010000100000?????????????????
???1??1202?00???10000???22100??1100111?0020210002022?021111021????????1
0?0??1?????1?0000??200????1?1222???0101?1?1?00000000000?0000?0001000010
000000000?00000??0100000000000000000?0????0???2???????????00???010000?0000
00000000000000??0????0?0000000?00000??01?000211111?1?111??11??00??10?0?
0011111112?00000?000?01121??00010001000000??0?000000001??000000???00?0
000?00?0?000

Herrerasaurus
0000010101000110000000100000110000001201010000000000010000100100021011??
?00001?11202000111100?0022210???110011110020210000022002211102100102
?1111100012110111100001?200111112122211101011101100000100000?000000001

0000100000000000000000001000000000000000100000000020000000013?01??010
000?0000000000000000000000???00000000000000010010000211111111111110
00001100000011111212100000?00000?12111111211?00000000000000000000?00
00001010000000000100000

Coelophysis
000001000100010101(0,1)011000001101000122101(0,1)0000000000?0010?1000?
101????00000?11202010111211000022210001100011110020200102012002101102
100112?1111100112110111201 0??2001?11??1222?11010111011010001001 00?0000
00001100010000000000000000000100000000000000000000000000300000000 13?01
??010000000000000000000000001000????000000000?10000100100002111111111 1
1111200001100100011111212100100000000112111111101111111111111111111100
1000000000??000000000 1111111

Liliensternus
00????????0???????0011?000???????????????0?000?1000000??????????????????00??
0?11202010011?00000??2210?011?0011??0020200102112002101202 1????????111
000121??11???20??2001111121222???01???????0??00?00100?0000000??0000?000
00?0??0?00??0??010000?00???????????????0????????????????????10000?000000000
00000000????????0?000?00???0000??01?000??1111111111?????00001100???0??11
???21????0??000??12??11?1101??????1???1????????00?0?????000?????00??011111
10

Zupaysaurus
?000?101010???????0011?00001001000122101010000000100??????????????????00
??0???????????????????????22???01??01??
?0?111??20??2001111121222???????????????0000001?0????????????????0000??????
?00000???1000000000000000000?00?000?3??????????????????1000??0000000000000
00001??0????0?000?000?10000??01?000??1111111111???1?????????????0?11?????2?
????0????0??1???????101?111111?????????????00????????????01?00???011?111?

Plateosaurus
0000110001000101001011001001100000122100000000000000000001001000210 11??
131000111002000011100000002221100111002110002020000202200210020210011(
1,2)?11101000021101112000 1?20011111212221110100010110000000000000010000
00000001001000010000000001010000000000000000000000000000000000000001??
040000?0000000000000000000000?0001000000001?0000010000001(0,1)1222?21112
20100200000100000011111112111111111111100200000000100000000000001000001
11111111111111111100000 1011000

Pantydraco
0010010101000???00?01?00000100100012010100000001000000000 10?????????????3
00?011?20200???????00???22????1110011??00202101000???????12?????1????????
0??021??11?00????????????????????01000101?00000?00000?0?00000??000000010
0?0???000000000000000000000000000?00?000?????????0??001??04000010000000
00000000000000?0001?00000000000001?0000012122???11122????00?0??1000000
111?????101?11??11?0002?00??00?1?000000000?????00011111?????1111000000??
000?100?

Antetonitrus

??
1?????0011???0????2200???110011??????????????2??021???021????????1010??0??1
??1????????????????????????0100?0?1?0???????0?0?0100?000???00???????????????
????0???0?000000000000000000????
?????000????????????????????????????????0???00?010?0000??????1????????1????
???0?00?0?0?????????????????000????1?1110??1?????11111???1??0

Eocursor
??0?0??????00000?
01?0???????2???????2210???110001???0202?0102032002001?021????????1??0??12
????????????????????????????11???1??????????00?0?00????0?10000???000?0????0
??????0???0???4?000?000000000000000000
?0??????0?00????????????????1111??221?12??2?1?1?211111211?1???????1?????????
?00???0?0??1??00????????????????????????0?????00????0?00??0?02???0

Heterodontosaurus
00101100010101100000?10000000100000122??1000000100000000???100??1??????
01010?0120100000?20000??22211?00110011111020210102032002001100210?????1
?10?00?120?0?1?2010????????????12220?11101110?100000000000?0000?00010000
1000000100000200??000000000000000000000?000000300000000?300???0400000
000000000000000000??0???0000011121112111211201213232222121121111120110
22011?110?0001020010?0?00000?010?010?00??000000?0??000000?100000000000
??00?000000002?000

Pisanosaurus
0?????????????????????????0???000001
???0??0????200????222??20??
11?1000??2?01???121222???11???10??0??????00?????????????00?0???00???????0??
????????0???4?00??000000000000000000?0
????00?00???????2???????1111????111?1222????????????00????????????20???????0?
1??????????0??????????????????00????????????????????0?????0?1?0?

Paleorhinus
1000020000000110000000100000000000000000100000000000000000000?000010000?0
00111000000000000100000?10?0010020000010000010020000000000000000000000?0??
???00000?0001000?11010?001000?0101100?000000100001000000000?0000100000
00011000000110111111112200121110000001000010000000100000000000102?10200
000?11?11010?01100000020100000110000000?000010001100061111111111111000000
00?000000000000?1001000?0??000000000000?001?0100000010?00000000000?000
010??1000000001020000

Rutiodon
1000020000000110000000100000000000000000100000000000000000000?????????????
011?0?000000000100000001000010020100010000000020000000000000000000000?0???
??00000?000?000???010100100000010110????????1????1000000000?000010000000
011000000110111111112211 1??1211100?10?0?00?10??121????01?011???0200000?
11?11010?011000000?0????001100000?00001??01100061111111111110000000?00
000??00000?1000000?0??0000?000?0001001?0000000010?00000000000?00001???
10?000000102010

Mystriosuchus
10000200000011000000000000000000000000000000010000000000?000010000?0
0011001000000000100????1???01002010001000000000200100000000000000000
0000000000?????????0?????????????????????????????1000000000?0?00100000000
110000001101111111123011200201101111212203212211111010112022020200000?
?11?11010?011000000?010000001100000?000010001100061111111111100000000?
00?????00000?????000?0??00???00???0??001?0000000??0??0????00000?00??10??1
000000?0102?100

Pseudopalatus
10000200000011000000000000000000000000000000000000000000?0000?0??????
01????????????????????????0100201000100?????????????????????000???????????
??000??00?11010?00100000010110???000001000?1000000000?0???10000??001100
00001101111111?21111012010101302021121020321111221101 21?2020000??11?
11010?011000000?0100?001100000?000010?01100061111111111100000??0???00?
0000000??000000?0????0?00?0??00?001?0000000?????00000000?0?00001???10?0
000?0102010?

Aetosaurus
000012111000000000001011?000000000000000110010000010000??????????????????1
0010????00????0?0?0??0?101011100000100??00002001000211?10001000000000000
000000000?000?11010?00??00?0101100?000001000000000000000?0000000000000
10000000000?00010??11000000000000000000????00???????????????0???021100?31
121102111130 2110??0???0001100000?00000??01?0012121111111220??00000?000
00000000????0?100?0??0000?000?000?001?010000??????0?000000?0?00001???00
?0000?01020000

Stagonolepis
0000121110000000000001000000000000000000110000000001002000000?0000?002111
1100101000000000100000010010101010000100?000002000000211011001000000?0
0000000000001?01?11010?00100000101100?0000010000000000000000?000000000
000010000000000000001000110000000000000000000000000000000000000010101??131
1000311211021111301110010?000001100000000000000010001112111111112200000
0000000000000000?0000100?0?000000000?0000001?0100000??0?000000000?0?00
0010??0000000000000000

Desmatosuchus
000012111000000001000100000000?0?0000011000000000100200000000000020?21??
11001010000000?0?0000?001010101010000100?10000200100021??1000100000000
000001001000100101101000010000010110??000001?000?0000000000?000000000
000010000000000000001001110000000000000000000000000000000000000010101??131
1?11122222212222322?220010?00000110000000000010000000150211111111220??00
000000000?000000???0?100?0??000?000??00?0001?0100000??0?00?000000?0?000
01???0000000?00020000

Longosuchus
00001211100???0??0101100000000100000001100100 0??????????????000??0?2????1
0010100000000001000??0????0101?100001000?000020010002??0???01000?00?000?
001000000??00?1101000010000010110??000001100000000??0000?0000000000000
10000000000000??00??10000000000000?00?0000?0??????????0???????131110132

122221222322?110?10?0?00011000000000???0?0001??211111112200000000?000
00000000??000010?10?00000?000?0000001?01000??????00000000??0?000010??00
?0000000020000

Ornithosuchus
00000101010000000010011?00001011000000100000010000020000000000???0?????
0010110?000000001001?001010001100010?000102000000121020002000000100
001000??01??001??102??????????101100?00000?100000000000000?0000000??001
0100000?0?000000000011010000000000000000000000200000000000001??010000
0021?110100001000021100??00000000110?000000001000031111111110?00?0000
01000????0000?00??100?0?000??0000?0010001?0100010??0???0?00000?00000000
??0000000?0001?000

Riojasuchus
010011010000000001001100100101100000010000000000002000000?0000?001???
?01100?000000000000100???0?0?0?011??0100?0?01020000000121020?0?0000?0?0??
010000?0101001?11020?001000000101100?000010100000000000000?00000000?00
1010000000?00?0000000?1010000000000000000000000020??????0???01??010000
0??????0?000010000002110????00??00110?000000?01000031111111110?00?000001
000000?0000?0000100?0?0000?0000?0?10001?01000100?0?00000000000?00000??
?00?00000000?1000

Dromicosuchus
0000010011000210000001?00001100101120101010011?200?11?0???????????????0
10???0??00000?0?000?10010101?120?0000?1?0?02001000?????????011??0?000?00
00000000000??001??????????10?1???????????????0000?00000?00??000????00?0000
0?0?0??00?00???1000000000000000000000000?31?0????0???0???0100??0021?110
10000100000??????11?2200000?0000???01?0001111111111112????????????????001
00???0?000?0?0000??000??0?100??010000?0?0???????002?0?????0???00?0000?01
??0000

Hesperosuchus
0000010?110?0210000001?00001100101120101010011?200?110000?????????????0
10???00100000?0?????1???0101?1?0?0000????????????????????????011??0?000?000
000?000000???????????????????????01??1????00000?00000?00??0000???0??00000
00?0??00000??110000000000000000000000000?31?0????0??10???0100001021?1101
0000100000?0???11112200000?0000???01?0001111111111112?00??????0000???001
00110?1000?0?0?????0001?001001?010000?00?2?00?00002002000????00?000000
10?0000

Pseudhesperosuchus
00000?0011000110000011?00001100?001201010?0?111200?010000?0???????????0
?????00100000?00???1??????0?1120?0001?????????????????????????0????0???????00
000000000??????????????????????????1????????0000000000?00000000???00?00000?
0?0?0000000?11000000000000000000?00000000310000000000010???0100?0???????0?
00001000000?1??00????00000?1000?0001?000311111111112?00??????0000???001
?0?????000?0?0?????000????1001?0100000??????????002?0?00??????00?0000001?
?000?

Terrestrisuchus

00000101100??????00111000011001000 2?0000100100200?1100001000?????1??1
01000?1000000000000001100201010120?0000011010200100012102000010000000??
000000001000000000010100100000101110000110110100000 0?00000?0000000000
0001000000010000000000011000000000000000?000000003100000001010???0100
00???????0?000010000000?11?01???00??0?000000000100 00??111111111?10000000
00000000001001 1??1????1?000?00000?000?001?01?0000??0200?000?0200200??00
???0?0000001020000

Erpetosuchus
0000000111000110000011100001000?00022111000011010001100 00????????????
00?00?0?0000001??????????01?11110?000
0??
???0000000000?0???1001??????000000?000?000000011000000000000000?0?10?00
0030?????????001??0100000121111010000100000 0?0???00?1200000000000?00?0
00211111?11111?0???????????????0000??0??000?0?0????0000??10?0?1?0000000?
????00???002?0?0000????00?000???1???010

Gracilisuchus
0010021111000?10000011?0000101000000110001001101002 11000??000???0?????
00000?0100000001000000100?1100100??0100?000002000000???????010000?0?0???
0011??010??00?00010?001?0??0101100??11000110000000000000?0000000??0000
000000?0?0?100010?011000000000000000000000000031000000000 00???0100000
12?1110100001000000000???00??20000000000000000000003111111111112????000??0
0000?0000?0???00000?0??0000?00??00?000??000000???0????000002?0?????10??0
0?0001?010?0000

Qianosuchus
00001101100000001011111000??0?0000?00????01000?00?020?0????????????????00
?00?1100??00??00??00???00?110?000000??101??00100010??100020000?0????????
???0????00???01??001?0?0010110???0?00?00000101000000 0?0000000??0000?000
00?0????000000??100000020?000000?0????00??30??????????01??0100?0???311?0
?0000?00000??0???00???0000?000000??00?000611111?1?111????0000???000?00?
001???0?100?0??00???0???00??001?000001????????000000?0??????0??00?000???1
?00100

Revuletosaurus
?000???0000?0210010111?0000?011000000??00?000?0200?0?????????????????? 00
????0000?0001??0???????01???00??0100?000002000000?????????0000?0?????0000
????????????010?0010000010110?????????????000000?000?????000????0???0000?
0????00000???00?00?????000000?0????000030??????????????040000?2?211?01000
0100000??????01?1?0000000000???00?000?12211?11222????0?0??01?????0?00???
?0???0?0??000??0???????00????0000????????????00??0?????1???00??00???10??000

Arizonasaurus
0000110100????????11010000011??0000001000?00000?00?0?00011?00001000000
0000?0101101010111111??11222?1?0000?????01012101000012102101200000 01000
0000000????0????????????????????????????????????0?0?00000??0??0????00????00
00?????000000??1100000??000000000000000000300000000????????100000000100
000000100000?0000000?000000000000000?010000??1111111111????0000001?????
01?00?????10?10??00??000?????0000?0000?0?0?0????????0000?????10??000?0???

0101?000

Arganasuchus
??????????????????10?1?0??000????
??0??0?????????????????????????????????????1??????000000000000100000000?
????11??????????????????????????????????0??0?????????????0000??000???????000?
0????0000????????????????????????????????????1?00?0???????????0??00??0?0???
??0?????00??0??????0100????1111111111???????0?11?????01??????????000??????
????????0?0????0???????????????????????????????????0???0?0??0??

Batrachotomus
00011101010002 0?001111?011100000010101010101101010?00000??10002001000
1010000000000101111000?012?1?1111?00100?0100110000002110210020000001 0
0000000???00000001101??????????10110???00??0?00000000000000??000000??00
00?00000?0?0?000000??1100000000000000000000000020000000000100???010000
01?2???010000200??0?0000000?2100001000000000010000211111111111???00000
0100??001000?????10010??00??000??00?0000?00000000?0??????000000?????10??
0001000000000000

Bromsgroveia
??
????????1?111??112??????????????01112101011 0???????1??00????????000???????
??0??????0?????00???????????????????
???0???0??00??????????
???????????????????????????????????????00?0????????0?????????????????00???????
??????????????????0?????????????????10??????00?????????0

Effigia
0010010100012201101011010001100000020110100000000 0?2111010?110211?1??
0201111101000100112 11??11?2210011?010???1001201011111211231121210101 0
110000?01?0110000000101001100001????00001011101011000?10000?0000000??0
000?000200000000 0?100??000000002000000000??0200000002000000?0??10???00002
00000000000000000000?100?0020000000000000010?00000050000000000?00?000
010?0000001?00?0?01000?0?0000?0000?1000000?100001???0??0?000101?0?????0
0000010001001200100

Fasolasuchus
?0??01????0001??001111?0000???10??
000000000101???0????10?????????????????????????1?2????0210?0?????10000?0?
??????11010100100000 10111??????????????0000???0????000?????0000?0000????0?
?00??0????000000000??????????????????????????????0???01?000?1?3???010000?00?
?0??????00???00000?00?????0100002111111111 11????000?11?????01??????0??00
?0?????????0??0??0?0?00?0????0??????????00?0????????0??0??00?000?0??000

Lotosaurus
0001110010012101100011?100001000010?0101000000?00020000???1000??01????
2110000000100101111 0?1110220????0000000100121000101?????????00000011?0
00000010001000000010100 1?0?0010110?????????????00000100???00?0?00????00
?0002??0?0?0000?0??100000000000000000000000000002000?00?0??00???000020?0
0000000000000000??00??02?0000000000010?0000005000000000000????0??0?01

00???00000???0?010?0??000??01???0?0000?000000?0?1??????010100?????0???00
?0001?002?0100

Poposaurus
??0?????????0??0
00001100112110?1112211?????0000?01012100111022102201202001010000000000
000?1?000??0101001100001011 1??????????????????????0?0?0?00?000?00001?????0
0000??010000000000000
0000???????????00??????????????????????????????????????0000001??0??0????????0???
?????00????0???0???0?????????????1??????0???????????00??????00?0???00??0

Postosuchus
0001010111100110000011000111 01?01000000100111011 0130?00001000120010??
00100?00000000001100011001??01011??0100001001000000002210220020000 0010
0000000010001000010010100110000101 11??00000?1000000000000000?000000000
0000?00000000000000000000?1000000000000000000000000000030000000000?01?1010
000?1?????0?0000?00??0000000000??00000000100000100002111111111111000000
00?01000000010000000100010?000000000?000000000000000???1000000000?0000
0010000001000?00000000

Prestosuchus
?10111011?0001000001 11?01111?0000?010??1010110001010?0?????????????????0
0000?????????1111001?00111?0111000100?01002?0000002??0210020000001000 0
0000000000000011010100100000101100000000001000000000000000???00000??000
0?00000?????000000??10000000000000000000????00?3000????0???0???0100?0?1?
1???010000200??0?00???00?2100000000000??01000021111111111????00000010
00000000????01000?0??0000?0???00?000??000000???0????000000???????100?00?
000??00?00000

Rauisuchus
??0??1??1????1000???1??0000?????????0????0?1?10?000?????0??????????????????0
00000000001010001?001?1?1?1????????01001100000 01?1020????????????????????
??00?00001101010010000????????????????????0000?00000??000?????00?0?00?00??
????00??0????0?0000000?????0?00????00??000?????????0???010??001?1???010000
200??0??????00?2100000??0?00???1??00??111?111111????0?000??00???0?00????0
?000????000??00??00??0??00????0?0?0????????0?00??????1???0??00??????20?00

Saurosuchus
010101011110011000001110000100010100010100011000001000000000000020010?0
0000???????????0101000??00110?????????????0100110000002?1021002000 0?0?????
00?0??00???00?1101010010000010111000000001000000000000?0??????0?????000?1
0000??????00000000?1000000000000000000000000000030000000001001?10100?0?1?
31??0100001000000000?00?0?21000000000000000010???211111111111????0000?01?
00000100????01000?0??00000?????????0000000000??0????000000???????1000000
00???000?0000

Shuvosaurus
00100101000121?1100?1011000111000002011010000000000221110101110211 11??
0201111110000 10???211??11122?0001??1000?1001201011111211231121210 10101
10000101001100 00?0010100110000 10110?0001011101010000000000?0000000??0

000?00020?0???0000100??1100000000000000010020000003000000?0?310???00002
?00000000000000000000000002?0000000000010?00000050000000000????000
010000000100????01000?0??00000?0??11?0?00?000001??00????000101?0?????0
0??001100??01200000

Sillosaurus
??1
001?11001?211??11????????????????01?12000?10?12102101?0000?0?????00?10???
??0????0?0?????000?????????????????
???00??????0?0000?0000?????
??0000?00?????0?????????????????????????
??????0?0???0???0??????0

Stagonosuchus
??00??????????????????????????????????00
1000000101000??001??????0??0100?01001?000000201021003???????????????????0
??000??0?0?00??00???????0????????
???????????????????0??0??0????0??????????????????????????0???????0?0000?0000????
???0????????????????????????0????????????????????0000????????0??????????????????00??
??0??????????????????????0?????????????0?????10???????0?????1???0

Teratosaurus
?001020111000100000011100101?1101?????????1?101001300000001?????????????0
00???0???000???????????01?1??????????????010011000000?????????????????????????
??000000????????????????????0000??????
?0001000?1000000000?0000000??00000?000????0??001?10100??01?21??0100001
00000000???00?210000000010?1?010?0?211111111111????0?0?????????01?0?????
?00000??00????0?????????00?000?00000???????0000??????1???00?1?????00??00?

Ticinosuchus
0???????????????????1111?0??00????
000000001??0??11???1000000000000?01000200000010?0200020000?0???????00??
000??00?11010?001000?01011?0?00000110?00???0???000?00000000000001?0000
00000?00??0??1?0??0????????0?????????????????????????????????01?0?0?1231??01000
0100000?0?????0021??00??00?????0100????1111?11111000000000?1000?00???0?0
001????0??0000??0000000?0????0????00??0000000??00?000010??????000?0?020?
00

Tikisuchus
000?????1?1???????0011?0?????????0?0?????0?0???10??20??????????120??0???01?0
00??1?1010?????????????????????????
??????010?00??0??010111?????????????????000?0???????????????00????000??????000
0?0????0000??????00??00?0?00??????????0??0?????????1000??????????????0??00??0?
??0??00?????00?00000?0?01?000??1111?1111????????00?????????1?0????0?????0??
??0??0????????0?????0?????????????????0???????????????????????????02???0?

Yarasuchus
0??????????1??2????1?01?0??????????????????0?0???????0?0?1?????????????????????????
1???00000?10000?0?1?101?10??0011?0100020000001?1020???0000?0???????000??
0001000??????????????????????????????????0?01?0?000?00?0?00??0000??0?00?0??

??00??0????0000??0????0?00?0????00???000?????????????10??001?11??01000010
0000???????0?21??00??00?0???????????1111?1?11?????0?00??100???01??0???????
0?0??00????0???0?0?0????0??0?0??????????0?00?????????????000?0??20?00