Dinosaur cladogram analysis answers

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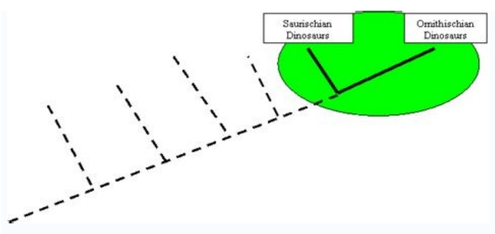

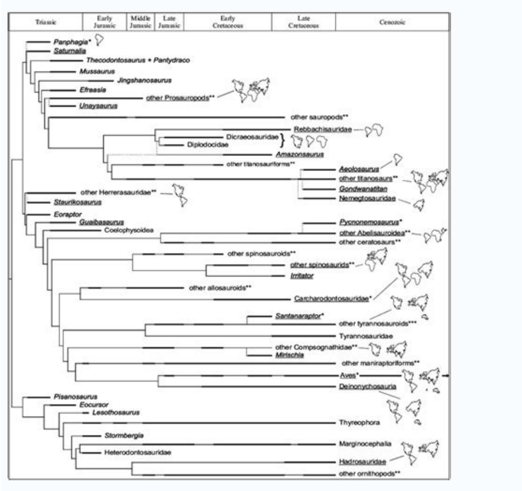

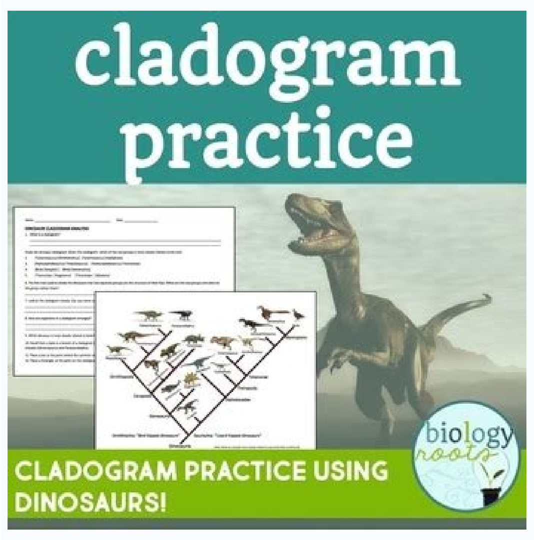

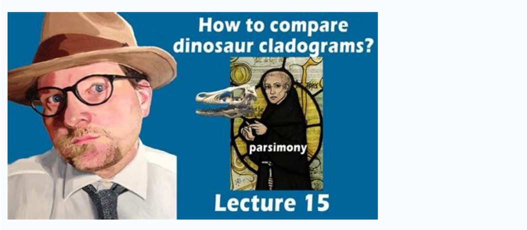

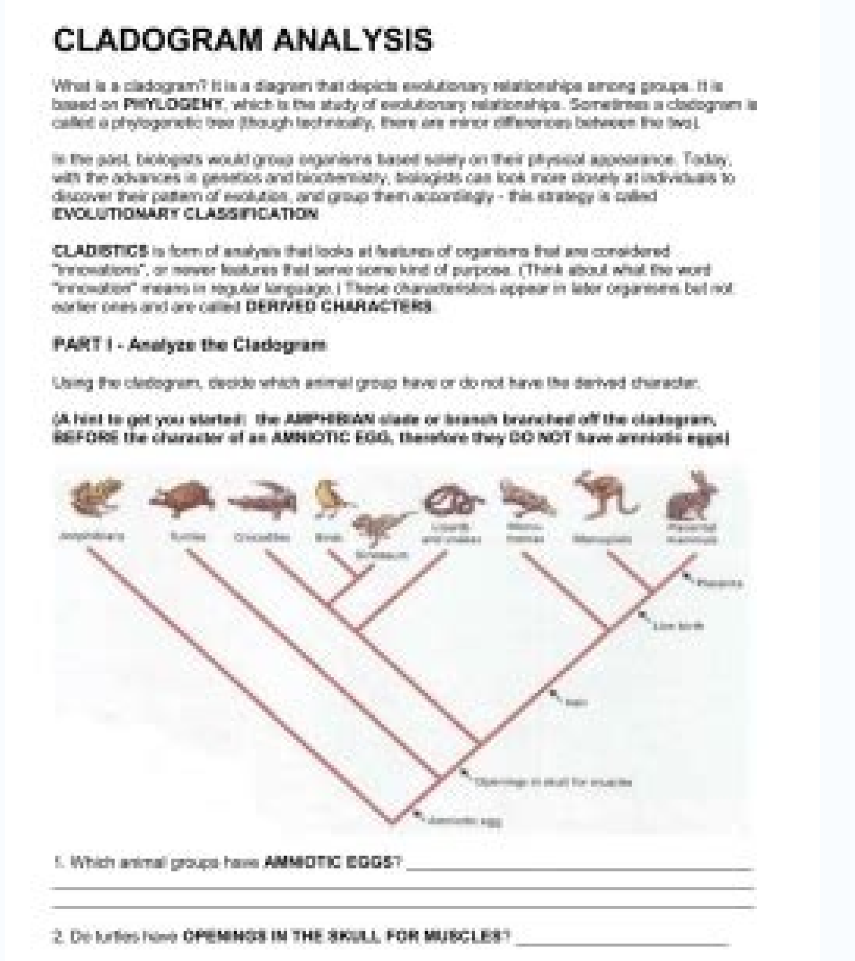

CLADOGRAM ANALYSIS

What is a cladogram? It is a diagram that depicts evolutionary relationships among groups. It is based on **PHYLOGENY**, which is the study of evolutionary relationships. Sometimes a cladogram is called a phylogenetic tree (though technically, there are minor differences between the two).

In the past, biologists would group organisms based solely on their physical appearance. Today, with the advances in genetics and biochemistry, biologists can look more closely at individuals to discover their pattern of evolution, and group them accordingly - this strategy is called **EVOLUTIONARY CLASSIFICATION**

CLADISTICS is form of analysis that looks at features of organisms that are considered "innovations", or newer features that serve some kind of purpose. (Think about what the word "innovation" means in regular language.) These characteristics appear in later organisms but not earlier ones and are called **DERIVED CHARACTERS**.

PART I - Analyze the Cladogram

Using the cladogram, decide which animal group have or do not have the derived character.

(A hint to get you started: the AMPHIBIAN clade or branch branched off the cladogram, BEFORE the character of an AMNIOTIC EGG, therefore they DO NOT have amniotic eggs)

1. Which animal groups have **AMNIOTIC EGGS?** ______________________________

2. Do turtles have **OPENINGS IN THE SKULL FOR MUSCLES?** ____________________

What is a cladogram answer key. Dinosaur cladogram analysis worksheet answers. Dinosaur cladogram analysis answer key.

Normally the dinosaurian world is rocked by a new fossil – the biggest, fastest, or toothiest. But the latest dinosaur research threatens to change our understanding of how dinosaurs evolved at a much deeper level, and blow aside 130 years of agreement on the topic. A new paper published in the journal Nature suggests that scientists need to reorganise the major groups used to classify dinosaurs. This means we may have to revisit what we think we know about the first dinosaurs, what features they evolved first, and where in the world they came from. The way we classify dinosaurs goes back to the 19th century. In 1887, Harry Govier Seeley, a classic, hard-working Victorian palaeontologist, divided dinosaurs into two major suborders based primarily on their hip structure. Saurischia comprises the flesh-eating theropods such as Tyrannosaurus and the ponderous, long-necked sauropodomorphs such as Diplodocus. Ornithischia comprises all the rest, including the two-legged Iguanodon, and the armoured, four-legged Stegosaurus, Triceratops, and Ankylosaurus. The old family tree. Zureks/Wikimedia, CC BY-SA This ordering of dinosaurs has stood the test of time for 130 years, weathering the onslaught of cladistics in the 1980s, when palaeontologists began using computers to analyse and categorise groups of animals based on features that pointed to a common ancestor. There are now thousands of diagrams (cladograms) of dinosaur subgroups, and ever-growing data matrices, that closely document the anatomical features of each species. The new paper completely disrupts the consensus over Seeley's categories. The researchers ran a cladistic analysis of 457 characteristics across 74 species (that is a data matrix of 33,818 bits of information recorded from skeletons). They concluded that, based on 21 unique characteristics of the fossils, the theropods were more closely related to the Ornithischia group and should be moved into that category. This would create a new group named Ornithoscelida and leave behind the Sauropodomorpha. The trick in cladistics is to find a unique anatomical feature that evolved at a specific time and can indicate a particular subgroup. For example, Seeley noted that the hip bones of ornithischians were arranged with pubis and ischium running backwards (superficially, like modern-day birds). Meanwhile, the hip bones of saurischians (including theropods) matched other reptiles, with pubis forwards and ischium back. The new tree. Matthew Baron/Nature This suggests the two groups split from a common ancestor and evolved different hip shapes. This was a massive anatomical change or novelty, and palaeontologists until now have assumed that it happened only once in evolutionary history. Grouping the theropods with the ornithischians suggests that the hip change occurred later and raises the question of whether some early theropods had this feature. The researchers also suggest that the new analysis can reset our understanding of where dinosaurs originated and what their diet was. The classic view was that the first dinosaur was a carnivore living in what is now South America. The new analysis makes this more of an open question and suggests they might have evolved as omnivores in the northern hemisphere. Tree of life None of this changes what we know for sure about what dinosaurs evolved which traits and when. But the key point is that accurately depicting the tree of life matters. If you care about modern biodiversity, it's important that all species are not equal. Some are more distinctive than others, possessing more unique features, and having a longer independent history. Working this out requires an accurate tree. On a broader scale, getting the tree right affects our calculations of rates of trait evolution, extinction and post-extinction recoveries. We will never find the very first dinosaur but we can establish some things about it by estimating the ancestral states of different species from a correct tree. We invest enormous efforts into constructing testable systems for categorising different species, and their size is increasing as computing power grows. When I ran my first cladogram in 1982, I had to use punch cards on a mainframe computer, and I could include only ten or 12 species and 50 or so characteristics. Today, I was able to run all the data for this new paper through my desktop computer and get an answer in 33.21 seconds, while writing this article at the same time. Recent publications have sported trees of all 10,000 species of birds, and even summary trees of all life. The dream is to run such trees with all 1.5m named species, using data about both genes and physical shape. Is this new paper the true answer for the evolutionary origins of dinosaurs? The data we have is riddled with question marks, and so the algorithms still struggle to calculate the one true tree. This is no criticism of the researchers, just a statement of the practicalities. We don't know yet whether we can see the wood for the trees. Sauropoda is among the most diverse and widespread dinosaurlineages, having attained a near-global distribution by the Middle Jurassic that was built on throughout the Cretaceous. These giganticherbivores are characterized by numerous skeletal specializationsthat accrued over a 140 million-year history. This fascinating evolutionaryhistory has fuelled interest for more than a century, yet aspects of sauropod interrelationships remain unresolved. This paper presentsa lower-level phylogenetic analysis of Sauropoda in two parts. First, the two most comprehensive analyses of Sauropoda are critiqued toidentify points of agreement and difference and to create a core of character data for subsequent analyses. Second, a generic-levelphylogenetic analysis of 234 characters in 27 sauropod taxa is presentedthat identifies well supported nodes as well as areas of poorerresolution. The analysis resolves six sauropod outgroups to Neosauropoda, which comprises the large-nostrilled clade Macronaria and the peg-toothedclade Diplodocoidea. Diplodocoidea includes Rebbachisauridae, Dicraeosauridae, and Diplodocidae, whose monophyly and interrelationships are supportedlargely by cranial and vertebral synapomorphies. In contrast, thearrangement of macronarians, particularly those of titanosaurs, are based on a preponderance of appendicular synapomorphies. The purported Chinese clade 'Euhelopodidae' is shown to comprisea polyphyletic array of basal sauropods and neosauropods. The synapomorphiessupporting this topology allow more specific determination for themore than 50 fragmentary sauropod taxa not included in this analysis. Their distribution and phylogenetic affinities underscore the diversity of Titanosauria and the paucity of Late Triassic and Early Jurassicgenera. The diversification of Titanosauria during the Cretaceousand origin of the sauropod body plan duringthe Late Triassic remain frontiers for future studies. Sauropods were the largest terrestrial vertebrates - theirestimated body mass exceeds that of other large dinosaurs by anorder of magnitude (Peczkis, 1994; Alexander, 1998). Despite the potential biomechanical constraintsat this extreme body size, sauropods were the dominant megaherbivorous group throughout 140 million years (Myr) of the Mesozoic, constituting approximately one-fourth of known dinosaur genera (Dodson &Dawson, 1992). Sauropod generic diversity increased throughtime, with peaks in the Late Jurassic of North America and the Late Cretaceous of South America (based on Hunt et al., 1994). The North American diversity peak may have extended into the Cretaceous, as new dis coveries of sauropods from Oklahoma(Wedel, Cifelli & Sanders, 2000a, b), Arizona(Ratkevitch, 1998), and Utah (Britt et al., 1998; Tidwell, Carpenter & Brooks, 1999) attest. The dearth of sauropod remains on poorly known southern landmassesmay also be to due poor sampling rather than a lack of fossil remains. Recent discoveries in Africa (Jacobs et al., 1993; Russell, 1996; Monbaron, Russell& Taquet, 1999; Sereno et al., 1999), Madagascar (Sampson et al., 1998; Curry Rogers & Forster, 2001), and Indo-Pakistan (Chatterjee & Rudra, 1996; Jain & Bandyopadhyay, 1997; Malkani, Wilson& Gingerich, 2001) have begun to reduce this bias.All known sauropods have a distinct, easily recognizable morphology:a long, slender neck and tail at either end of a large body supported by four columnar limbs (Fig. 1). The anatomical details of this architecture are unique to sauropods and have furnished the basic evidence of their monophyly (e.g. Marsh, 1878, 1881; Romer, 1956; Steel, 1970; Gauthier, 1986; McIntosh, 1990). Based on comparisons with the saurischian outgroups Prosauropoda and Theropoda (Gauthier, 1986; Sereno et al., 1993), early sauropod evolution was characterized by an increasein body size, elongation of the neck, and a transition from bipedalto quadrupedal progression. These and many other sauropod synapomorphies must have arisen during the 15–25 million-year intervaldefined by their hypothesized divergence from other saurischians 225–230Myr ago (Mya) (Flynn et al., 1999)and their first appearance in the fossil record, 206–210Mya (Buffetaut et al., 2000; Lockley et al., 2001) (Fig. 2). Open in new tabDownload slideSilhouette skeletal reconstruction of Dicraeosaurus hansemanni in right lateral view. The reconstruction is based on a partial skeleton(HMN skeleton m), which includes a partially articulated vertebralseries from the axis to the 18th caudal vertebra (including ribsand chevrons), a pelvis, and a hindlimb lacking the pes (Janensch, 1929b; Heinrich, 1999: fig. 19). Elongate, biconvex distal caudalcentra were collected at sites s and dd, but the length of this series is unknown (McIntosh, 1990: 392). The presence of a 'whiplash' tail of 20 or moreelongate, biconvex caudal centra is equivocal for Dicraeosaurus(Wilson et al., 1999: 594). A 'whiplash' of intermediate length has been reconstructed here. The forelimb was based on a second specimen (HMN skeletono) preserving a scapula, coracoid, humerus, and ulna in associatio nwith caudal vertebrae, a pelvis, and a partial hindlimb (Heinrich, 1999: fig. 6). Missingelements of the manus and pes were based on those of Apatosaurus(Gilmore, 1936); missing cranial elementswere based on Diplodocus(Wilson & Sereno, 1998: fig. 6A). Open in new tabDownload slideTemporaldistribution and relationships of major lineages of dinosaurs duringthe Triassic and Jurassic. The asterisked grey bar represents theghost lineage preceding the first appearance of sauropods in thefossil record. The diagnostic features of Sauropoda evolved duringthis implied 15–25 million year interval. Icons from Wilson & Sereno (1998) and Sereno(1999); timescale based on Harland et al.(1990).A broad range of variation is present within this basic body plan, providing a basis for more than 70 named sauropod genera. Of these, the few that are known from cranial remains indicate atleast two different general skull morphs (Fig. 3). One sauropod subgroup, Diplodocoidea, has a long, low skull with a rectangular muzzle thatterminates in a reduced set of pencil-like teeth. In contrast, macronarianssuch as Brachiosaurus and Camarasaurus have tall skulls withlarge, laterally facing nostrils and rounded jaws invested withlarge, spoon-shaped teeth. Cranial material of the basal titanosaur Malawisaurus (Jacobs et al., 1993), theisolated skull of Nemegtosaurus(Calvo, 1994%; Wilson, 1997), and newly discovered material(Calvo, Coria & Salgado, 1997; Martinez, 1998) suggest a distinct skull morphology for titanosaurs that can be interpreted as a variationon the basic macronarian skull morph. The recently described skull of Rapetosaurus (Curry Rogers & Forster, 2001), which was preserved in association with definitive titanosaur postcrania, confirms this assessment. The sauropod vertebral column varies both in its length and morphology. The number of presacral vertebrae ranges from 24 to 31, the sacrumconsists of between four and six co-ossified vertebrae, and thetail includes from 35 to more than 80 vertebrae. The presacral centraand neural arches of sauropods are characterized by numerous bonystruts that connect the costovertebral and intervertebral articulations, centrum, and neural spine (Fig. 4). These bony struts, or vertebral laminae, enclose discrete fossae that in life may have been filled by pneumatic diverticulae, or outpocketings of lung epithelium (Britt, 1997; Wedel et al., 2000b). Thearchitecture of these vertebral laminae is particularly complexin sauropods compared to that in other saurischians and phylogenetically informative at higher and lower levels (Bonaparte, 1999; Wilson, 1999a). Sauropods are also characterized by various tail specializations, includingthe fusion of the distalmost three or four caudal vertebrae into a bony tail club in Shunosaurus(Dong, Peng & Huang, 1989), and the short series of mobile, biconvex caudals in neosauropods, which is modified into a 'whiplash' tail in diplodocids (Holland, 1906) (Fig. 5). Open in new tabDownload slideVertebral laminae in cervical (top) and dorsal (bottom) vertebrae of Diplodocus. Both vertebrae are in right lateral view. Modified from Hatcher (1901: pl. 3, fig. 14;pl. 7, fig. 7). Abbreviations based on Wilson (1999a): acpl = anteriorcentroparapophyseal lamina; c = coel; cpol = centropostzygapophyseallamina; cprl = centroprezygapophyseal lamina; di= diapophysis; hpo = hyposphene; nsp= neural spine; pa = parapophysis;pc = pleurocoel; pcdl = posterior centrodiapophyseallamina; pcpl = posterior centroparapophyseal lamina; podl = postzygodiapophyseallamina; poz = postzygapophysis; ppdl = parapophyseal diapophyseallamina; prdl = prezygodiapophyseal lamina; prpl = prezygoparapophyseallamina; prz = prezygapophysis; spdl = spinodiapophyseallamina; spol = spinopostzygapophyseal lamina; sprl = spinoprezygapophyseallamina. Scale bar = 20 cm. Open in new tabDownload slideFiverecent cladistic hypotheses of sauropod relationships. Each hasbeen simplified for ease of comparison and to reflect higher-levelgroupings. Aside from variation in the number of carpal, tarsal, and phalangealelements, sauropod appendicular elements appear more conservativethan other parts of the sauropod skeleton. Titanosaurs may be anexception, as limb specializations were particularly important inthe acquisition of their derived 'wide-gauge' limbposture (Wilson & Carrano, 1999).Major questions surrounding sauropod evolutionary history canbe evaluated in the context of a hierarchy of relationships based on the distribution of morphological features within the group. Interest in sauropod relationships has produced quite disparateviews of sauropod descent, which necessarily imply different evolutionaryhistories for the group. The present analysis is an attempt to betterour understanding of the lower-level relationships of Sauropodaby evaluating character data from previous analyses, as well as novelcharacter information generated from collections research. The firstsection of this paper will elucidate points of similarity and difference between recent cladistic analyses, focusing specifically on coding assumptions, scoring, and topology in the two most recent and thorough cladistic treatments of sauropods. This section will underscorethe main differences in these views of sauropod relationships, aswell as produce a core of characters for use in subsequent analyses. The second section of the paper will analyse a wide range of anatomical characters across a broad sampling of genera to generate a hypothesis of the lower-level relationships of Sauropoda. ABBREVIATIONS Institutions. AMNH, American Museum of Natural History, New York; HMN, Museum für Naturkunde der Humbolt-Universität, Berlin; ISI, Indian Statistical Institute, Calcutta; PVSJ, Museode Ciencias Naturales, Universidad Nacional de San Juan, San Juan. RECENTCLADISTIC ANALYSES HIGHER-LEVELCONSENSUS AND SUMMARY In an effort to achieve a general consensus of the higher-level relationships of sauropod dinosaurs, topologies of the cladisticanalyses of Calvo & Salgado (1995), Upchurch (1995), Salgado, Coria & Calvo et al. (1997), Upchurch (1998), and Wilson& Sereno (1998) are compared here. Consensus trees were generated from the published topologies, which differ considerablyin the number of taxa and characters included (Table 1). For ease of comparison, lower-level taxa were subsumed into higher taxa whereappropriate (Fig. 6), and the topologies of these five simplified hierarchies were comparedin both strict and 50% majority-rule consensus cladograms(Fig. 7). The minimumnumber of topological rearrangements separating each of the topologiesis listed in Table 2. . C & S (1995) . U (1995) . S (1997) . W & S (1998) . U (1998) . C & S (1995) – 3 2 2 2 U (1995) – – 2 5 2 S (1997) – – – 0 0 W & S (1998) – – – – 3 U (1998) – – – – – A strict consensus tree generated from the five analyses preservesonly one internal node, Eusauropoda, comprising nine unresolved taxa (Fig. 7). The50% majority-rule consensus tree offers more resolution, maintaining two additional nodes, Neosauropoda and Titanosauriformes (Fig. 7). Unresolved taxa in the 50% majority-rule tree correspond to Barapasaurus, the Chinese taxa that Upchurch (1995, 1998)places in 'Euhelopodidae', Haplocanthosaurus, and Camarasaurus. Variant interpretations for each of these taxa are outlined below.The phylogenetic position of Barapasaurus amongst non-neosauropodsdiffers only in the analyses of Upchurch (1995, 1998) and Wilson & Sereno (1998). Upchurchconsidered Barapasaurus more basal than Shunosaurus, whereas Wilson & Sereno resolved Barapasaurus as moreclosely related to neosauropods than is Shunosaurus. Becauseneither Calvo & Salgado (1995) nor Salgado et al. (1997) included more than two basal sauropod taxa, their placement of Barapasaurus is consistent with either hypothesis. Barapasaurus is known from more than 205 postcranial elements (Jain et al., 1979), but only a fraction of these has been described and fewer illustrated. Missing information, then, may play an important role in the lack of phylogenetic resolution for Barapasaurus. Wilson & Sereno (1998) identified sixsynapomorphies nesting Barapasaurus more closely to neosauropods thanis Shunosaurus, whereas Upchurch identified only two featuresthat unambiguously maintain Shunosaurus as more derived than Barapasaurus, one of which is homoplastic (CI = 0.167).The Chinese taxa Shunosaurus, Omeisaurus, and Euhelopus, in contrast, are among the most complete sauropod genera known, so missing data cannot be invoked to explain radically differentinterpretations of their descent. Three analyses, Upchurch (1995, 1998) and Wilson & Sereno (1998), include these three Chinese taxa (see Fig. 6). A fourth, Mamenchisaurus, was included byUpchurch (1995, 1998) but not by Wilson & Sereno (1998). Upchurch's analyses found support for the monophyly of these Chinese taxa and placed them as the sister-taxon to Neosauropoda in the clade Eusauropoda.Wilson & Sereno (1998), in contrast, resolved these same Chinese taxa as a polyphyletic assemblage, with Shunosaurus as the basal eusauropod, Omeisaurus as the outgroup to Neosauropoda, and Euhelopus asthe sister-taxon to Titanosauria in the clade Somphospondyli.Different topologies predict different timing and sequence of phylogenetic branching in a group's evolutionary history, so measures of stratigraphic congruence may help resolve topologicalconflict (Wagner, 1995). The minimum implied gaps for both phylogenies were calculated and compared (Fig. 8). Both the Wilson & Sereno (1998) and the Upchurch (1998) hierarchies require four missing lineages, three of which accrue during the Early and Middle Jurassic. These hierarchies, however, differ in the total implied gap as well as the distribution of that gap. The Wilson& Sereno (1998) hypothesis predicts a larger gap (85 Myr) than does the Upchurch (1998) topology(75 Myr). Scaled to total lineage duration (140 Myr), these minimum implied gaps represent 61% and 54% of sauropodhistory, respectively. This discrepancy is due to differing interpretations of basal sauropod taxa. Because it is stratigraphically costlierto resolve the Middle Jurassic Shunosaurus as morebasal than the Early Jurassic Barapasaurus, Upchurch's(1998) hypothesis implies less stratigraphic debt than does that of Wilson & Sereno (1998). Both hypotheses accumulate the majority of their stratigraphic debt in the Earlyand Middle Jurassic, which may indicate that these levels have notbeen adequately sampled (Wagner, 1995). The apparently simultaneous evolution of all other neosauropodsin the Late Jurassic (Kimmeridgian−Tithonian) underscoresthis assessment - better sampling of earlier intervals will help resolve the origin of neosauropod lineages as well as that of basal eusauropod taxa. Thus, neither missing anatomical datanor missing stratigraphic information account for differing

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