The evolution of sauropod dinosaurs

May 12 2016, by Jon Tennant

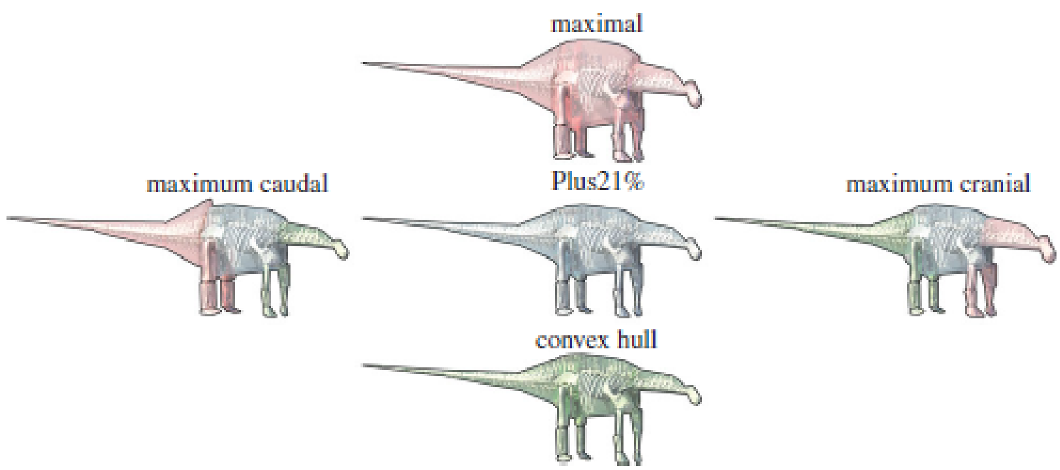
Sauropod dinosaurs are some of the most notoriously recognisable animals. With their whiplash tails, and long searching necks, they are the biggest terrestrial vertebrates ever to walk the Earth.

One factor that has received much attention from a range of scientific disciplines is the evolution of gigantism: how and why did sauropods get so damn big? Many sauropods were up to an order of magnitude than the biggest mammals, and they had a distinct body plan to accompany and accommodate this, with stocky, columnar limbs and a tank-like torso.

But what does 'big' mean? And how do you measure 'big' in fossil species?

Size is a multi-dimensional factor. For example, what is bigger, a 3 meter long snake, or a 3 metre tall giraffe? They are both equally 'big' in one dimension, and 'bigger' than the other based on it. What about a one tonne elephant – is that bigger than a 3 metre tall giraffe or a 3 metre long snake?

Size takes on different dimensions, and is important for a number of reasons. Size confers a survival advantage on an animal, for example – the bigger you are, the less risk you're at from predation. Unless your predators grow equally in size too, in which case you get predator-prey escalation in a sort of arms race. Similarly, small size can often be a good thing too – imagine a 15 metre long sauropod trying to fly!

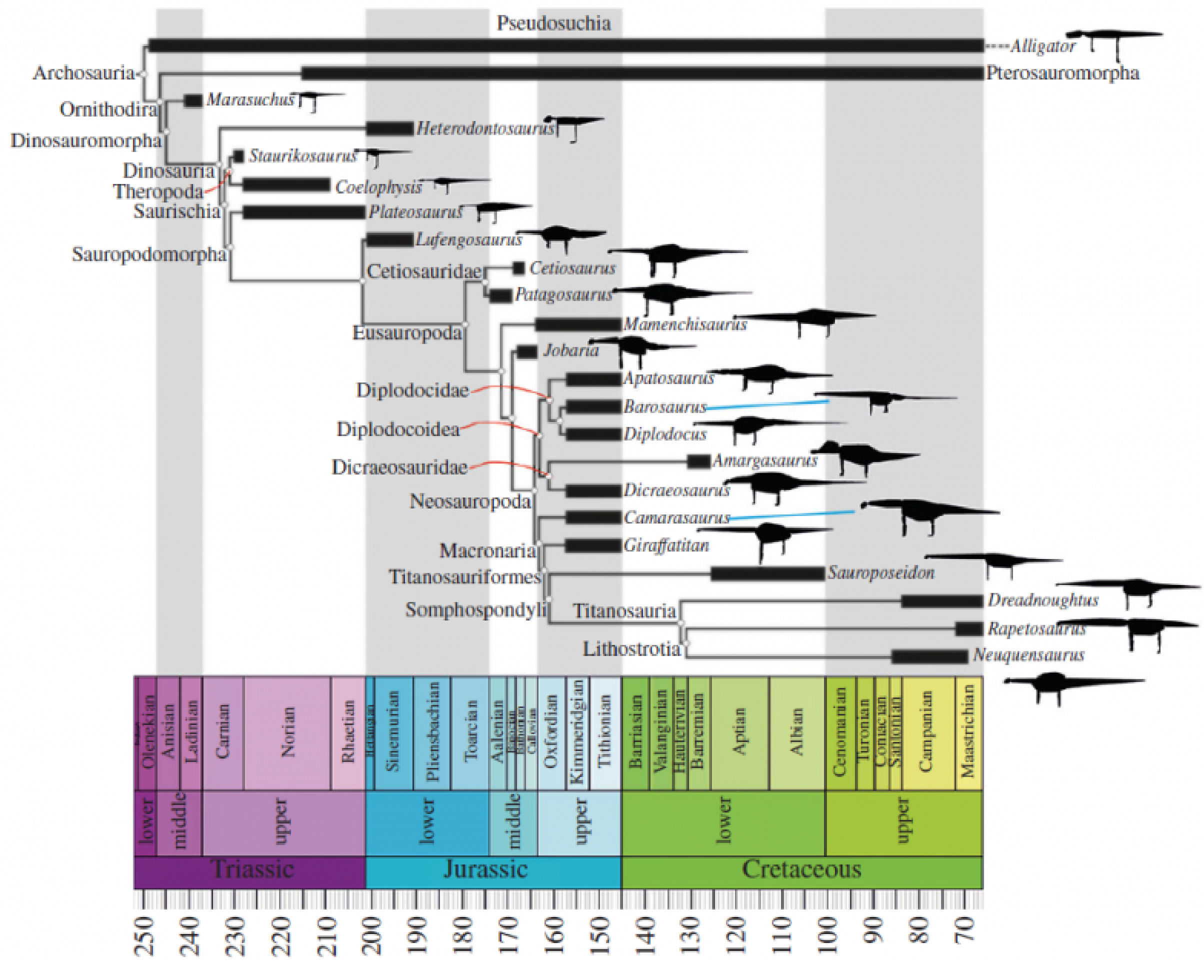


Estimating the sizes of sauropods – which one is best?! Credit: Bates et al. (2016)

So big is complicated, and when we're talking about sauropods, 'big' or 'gigantic' can refer to their enormous height, length, or body mass. If the fossil record were kind, we would be able to calculate these things easily. But as readers of this blog will know, the fossil record is rarely kind, and often cruel.

We often only have scraps of dinosaur, a bone here or there, perhaps a few articulated skull elements or a limb. Very rarely do we get a complete dinosaur which we can accurately estimate size from. So how do we accurately estimate the size of sauropods, and place this into an evolutionary context?

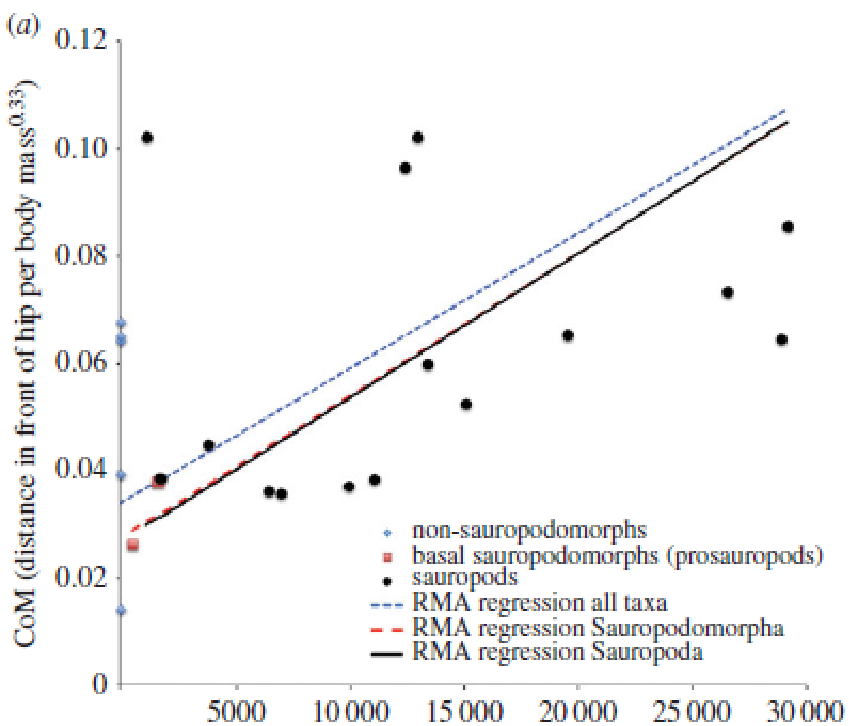
Karl Bates from the University of Liverpool (UK) and an international team of colleagues set out to answer these question using what are informally known as 'kick ass' methods.



The evolutionary relationships of all sampled sauropods. Credit: Bates et al. (2016)

Previously, size has been estimated in extinct dinosaurs by using proxies, such as the length of the femur or the total length of the body. From this, we generally know that sauropods evolved from smaller, bipedal animals into the quadrupedal titans we perhaps know best. Previous studies have estimated the mass just of one or two exceptional sauropod species, which doesn't tell us much about evolutionary trends, and is more about understanding evolutionary limits, or sometimes even just something for a bit of media grabby attention. Bates and the team sampled sauropod species from across their evolutionary tree, totalling 17 species in all.

Not only did they have a much wider temporal and phylogenetic coverage than all previous studies, but they also used really cool methods based on automated computational volumetric to estimate their body sizes.

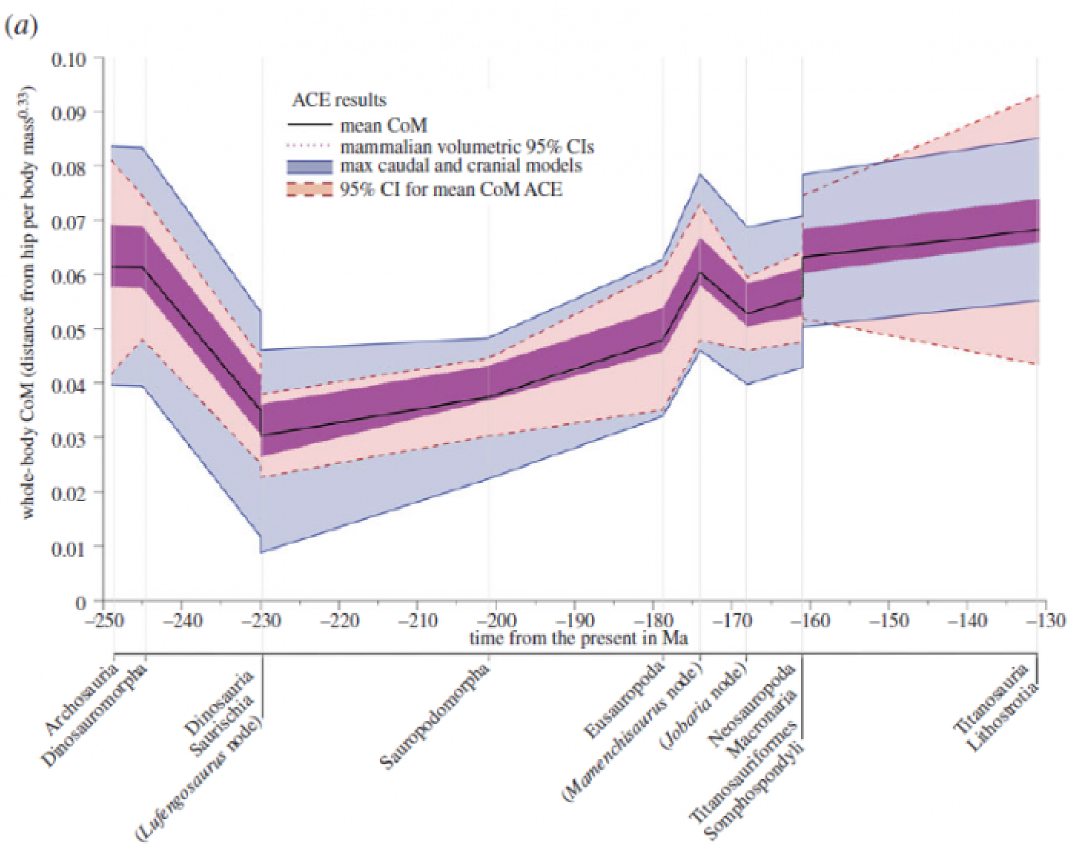


The relationship between centre of mass and body mass for sauropods. Bates et al. (2016). The lines represent reduced major axis regressions.

Fire the "laser"

They used a long-range laser scanning technique and digital photogrammetry to create computer models of entire sauropod skeletons. To reconstruct the fleshy parts of each animal, a convex hull approach was used which fits three-dimensional polygons around different sections of the skeleton to digitally represent the volume of each animal. This provides a baseline minimal body size estimate, and the team played with this to test the sensitivity of results by increasing the volume of the convex hulls to represent different body proportions. As such, estimates of body size contain large error bars, which is needed for calculations like this in which there is a lot of potential uncertainty.

What the team found is perhaps intuitive, but cool nonetheless. It seems that all major changes in body size within sauropods and their ancestors (sauropodomorphs) are related to major macroevolutionary events in the history of the group.



How has the center of mass of sauropods changed through time? Credit: Bates et al. (2016)

In the Middle Triassic (245-230 million years ago), when dinosaurs were just getting going, there is evidence for shift in the centre of mass of saurischian dinosaurs (early theropods and sauropodomorphs). This tail-wards shift in centre of mass seems to be associated with the evolution of bipedalism in these early dinosaurs.

However, this change was reversed by the Late Triassic, as sauropods became more graviportal and took to four legs to support their increasing body sizes during the Early to Middle Jurassic. This constraint to using four limbs to walk is called 'obligate quadrupedalism'.

Later on in their evolution during the Late Jurassic (around 161 million years ago), this reversal becomes more prominent as the centre of mass moved more towards the skull, particularly striking in the titanosauriforms – the sauropod group that included the largest species of all (in case you didn't get that from the name..)

Centre of mass shifts towards the front end of the animal are each associated with lengthening of the neck, a trait that was probably one of the most important factors in the evolution of gigantism in sauropods. A longer neck gives an animal a greater 'feeding envelope' and it becomes more efficient in gathering food. Additionally, it means you can reach food that other smaller herbivores are incapable of. And trees thought they were so smart..

These shifts are also related to changes in locomotory habit and environmental distributions in titanosaurs. For example, some sauropods had what is called a 'narrow gauge' stance while others had a 'wide gauge', which relates to the relative distances between pairs of legs beneath the torso. Wider gauge trackways are those in which the legs are planted further away from the midline of the animal. The evolution of this 'wide gauge' stance is coincident in time with the evolution of a more cranial-positioned centre of mass, and development of a greater neck length.

Also, it seems that some subgroups of sauropods preferred to inhabit coastal environments, while others dwelled more inland in freshwater habitats like lakes and rivers. Whether this environmental differentiation had a role to play in the evolution of sauropods remains to be seen.

What we do know now though is that estimating the size of dinosaurs is complicated! But researchers are making great strides to measure this, while understanding the limits of what current technology can tell us. By doing so, they're slowly unlocking the constraints placed on the evolution of life, and that's pretty awesome.

More information: Karl T. Bates et al. Temporal and phylogenetic evolution of the sauropod dinosaur body plan, *Royal Society Open Science* (2016). DOI: 10.1098/rsos.150636

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