The evolution of tyrannosaurs

February 18 2016, by

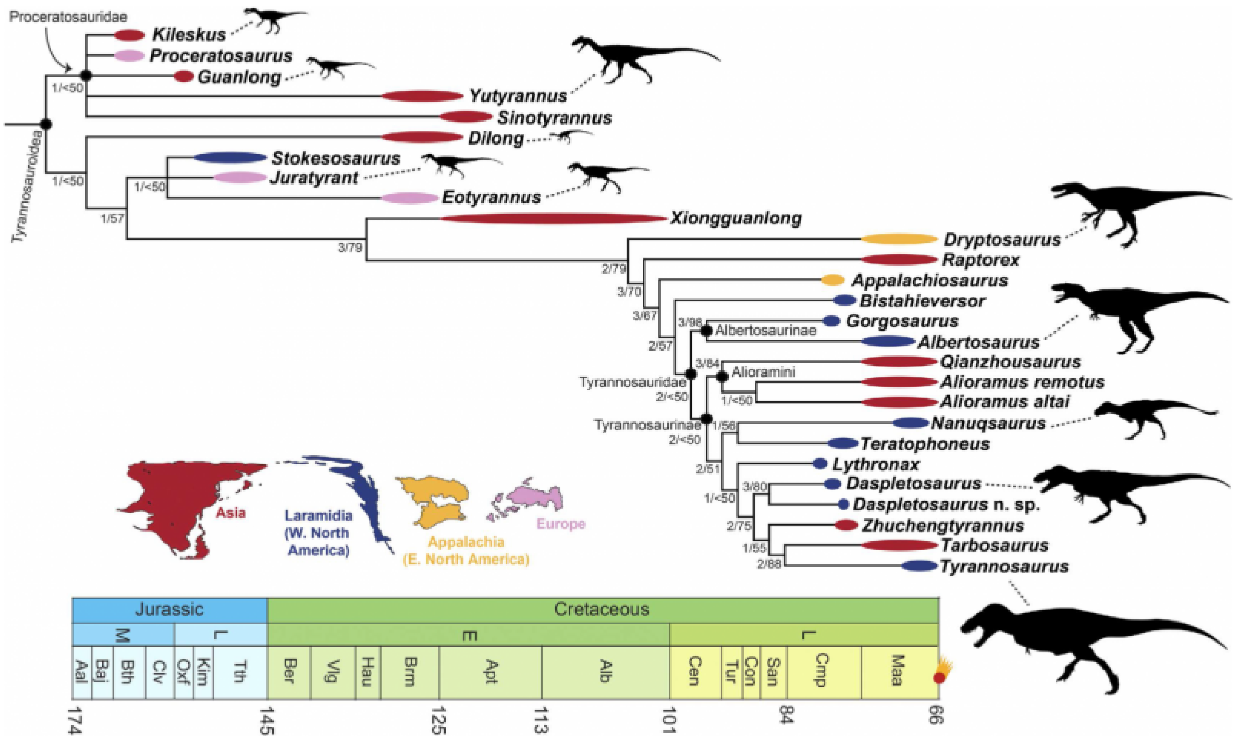
‘Sue’ specimen of T. rex from the Chicago museum

T. rex is probably the most notorious and infamous dinosaur of all time, and somewhat of an icon in both the scientific and public spheres. After all, it was a pretty fearsome and impressive carnivore, and arguably worthy of such admiration. But there were actually a lot of other dinosaurs similar to T. rex, together forming a group known as tyrannosauroids.

Recently, a whole series of new findings is helping us to unlock the secrets of these fascinating beasts, and we can now begin to answer questions about their evolutionary relationships, biogeography, and how decent their fossil record is. In fact, half of all known tyrannosauroid species have been discovered in the last decade alone!

Tyrannosauroid species were actually around way before T. rex, which only occupied the top of the food chain right at the end of the Cretaceous reign of the non-avian dinosaurs. Actually, the largest tyrannosauroids only seemed to appear around 20 million years before this. Before they achieved such terrifyingly gigantic sizes, most were actually quite small-bodied (for a dinosaur), and quite ecologically diverse.

Steve Brusatte, Thomas Carr and their colleagues visited the question of the inter-relationships of tyrannosauroids back in 2010. Forming hypotheses of relationships like this forms the basis for assessing important evolutionary factors, such as the origins and evolution of particular anatomical features, rates of evolution, diversity, anatomical disparity, and biogeography. So when another study produced alternative results to their earlier study, Brusatte and Carr decided to go back to the Mesozoic and reanalyse tyrannosauroids, but incorporating all of the recent bits of knowledge we have gained about them over the last few years.

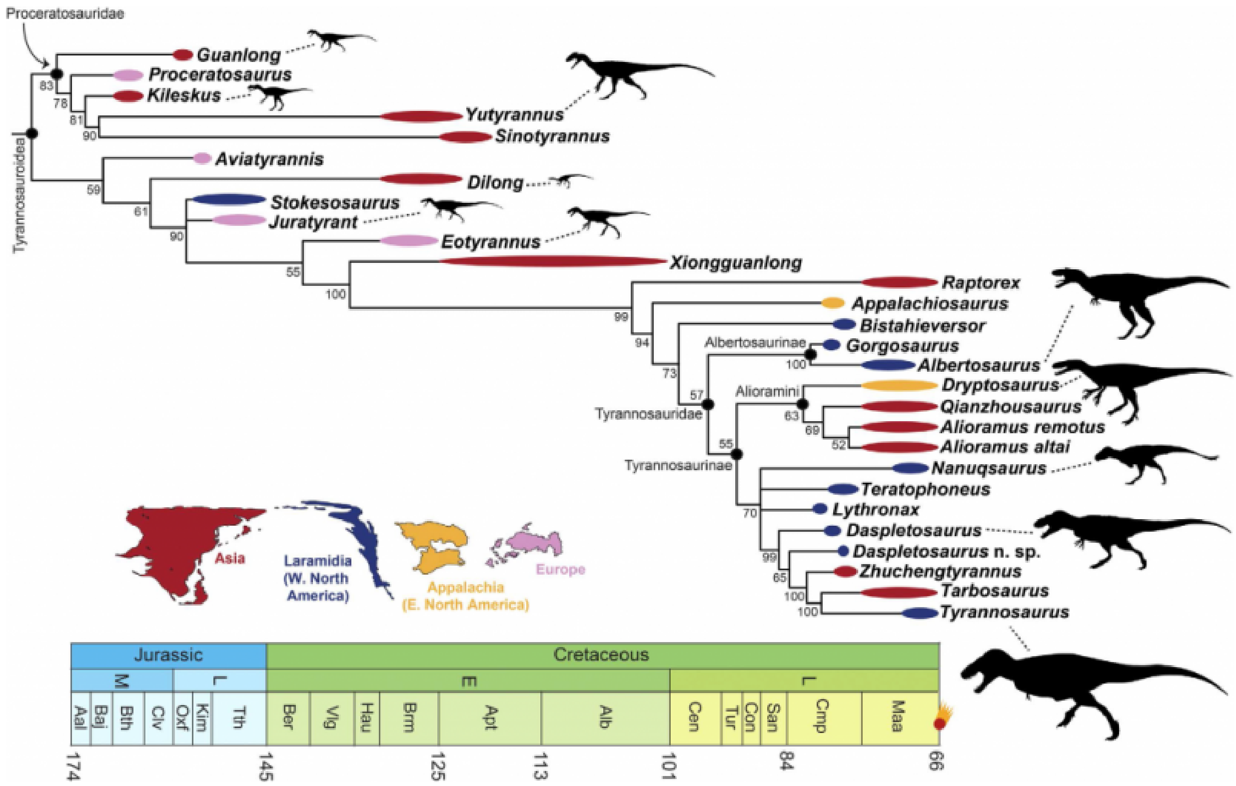


obtained using parsimony methods. Credit: Brusatte and Carr, 2016

In addition to this, Brusatte and Carr decided to approach this with a dual method. Typically, when palaeontologists create trees that form the basis of assessing evolutionary relationships, we use a method called parsimony. This looks at how many different anatomical changes have occurred between different species, and tries to provide the minimum number of changes in order to build a tree. They also decided to go Bayesian on their dataset though, something which hasn't really taken off in palaeontology yet, and has been more widely applied to molecular analyses. This works slightly differently by analysing anatomical data (in the form of a character matrix) in a probabilistic framework, and by using more complicated models that treat characters in different ways. By using this combination of techniques, it is possible to see which results are congruent, and therefore which conclusions can be best supported.

Fortunately for Brusatte and Carr, the results of both analyses were quite similar overall, lending support to their conclusions. There are slight differences, which you can see by comparing the two trees figured here. The overall structure reveals that tyrannosauroids can be sub-divided into a basal clade of proceratosauroids, which includes taxa such as the feathered Yutyrannus and Guanlong; an intermediate grouping or grade of small- to medium-sized beasties; and the gigantic apex predators such as T. rex and Tarbosaurus that we all know thanks to the best scientific minds in Hollywood.

The authors do a great job of trying to work out why their results differ slightly, but as always, the devil is in the details and it can be quite difficult to figure out. Part of the reason for some of the discrepancies might be to do with missing data – we can never fully sample every organism that has lived, and palaeontologists accept that limit of the fossil record. In the case of tyrannosauroids, there is a 20 million year gap in their fossil record from just before the time when the Western Interior Seaway covered much of North America. What this means is that animals simply weren't preserved in the right time in the right place to be preserved as fossils. Yet, at least. Discovering new tyrannosauroids from this gap might be critical in working out how more derived tyrannosauroids evolved during a clearly important time in their history.



obtained using Bayesian methods. Credit: Brusatte and Carr, 2016

But what does all of this mean then for the evolution of tyrannosauroids? Well, for starters, it shows that the evolution of their large body size appeared to happen more gradually, rather than a rapid burst. Accompanying this, it shows that bite forces increased incrementally too, and that their elaborate facial ornamentations gradually became more complicated along with increasing body size. The first truly gigantic tyrannosauroids, coming in at more than 1.5 tonnes in mass and 10 metres in body length, didn't appear in the fossil record until around 80 million years ago.

In terms of their biogeography, some interesting patterns emerge. It seems like there was episodic interchange between Asia and North

America during the Late Cretaceous. What this means, and I'm sure Donald Trump will love this, is that T. rex actually appears to have been an Asian immigrant that colonised North America. However, this understanding might change as we recover ever more tyrannosauroid fossils from the latest Cretaceous of Asia and North America.

So, that's a quick update on what we know about tyrannosauroids. Despite them clearly winning a cross-dinosaur popularity contest, there is still much we can learn about these creatures, and only time and future exploration can tell what we'll discover!

More information: Mark A. Loewen et al. Tyrant Dinosaur Evolution Tracks the Rise and Fall of Late Cretaceous Oceans, *PLoS ONE* (2013). DOI: 10.1371/journal.pone.0079420

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Stephen L. Brusatte et al. The phylogeny and evolutionary history of tyrannosauroid dinosaurs, *Scientific Reports* (2016). DOI: 10.1038/srep20252

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