T. rex had huge growth spurts, but other dinos grew 'slow and steady'

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Paleontologist Tom Cullen cutting into SUE the T. rex's thigh bone to learn how T. rex grew. Credit: © David Evans

Tyrannosaurus rex was one of the biggest meat-eating dinosaurs of all time—it measured up to 42 feet long from snout to tail and would have weighed in at around 16,000 pounds. And it wasn't alone—some of its less-well-known cousins could reach nearly the same size. Scientists have

previously shown that *T. rex* got so big by going through a huge teenage growth spurt, but they didn't know if that was true for just tyrannosaurs, just them and their close relatives, or perhaps all big bipedal dinosaurs. By cutting into dinosaur bones and analyzing the growth lines, a team of researchers got their answer: *T. rex* and its closest relatives had an awkward adolescence during which they got huge, while its more distant cousins in the allosauroid group kept on growing a little bit every year.

"We wanted to look at a wide swath of different theropods, two-legged, carnivorous dinosaurs, in order to understand broader patterns of growth and evolution in the group," says Tom Cullen, the lead author of a new study in *Proceedings of the Royal Society B*.

Cullen, a scientific affiliate of Chicago's Field Museum who worked on the study as a postdoctoral researcher at the Field with the museum's then-curator of dinosaurs, Pete Makovicky, explains, "We particularly wanted to understand how some of them got so big—is the way *T. rex* grew the only way to do it?"

Makovicky, a scientific affiliate of the Field and professor of geology at the University of Minnesota and the paper's senior author, says, "We also wanted to see if we got the same growth record when we sampled a variety of different bones from the same skeleton. All these questions about how theropods grew could impact our understanding of the evolution of the group." Makovicky developed the idea for the project and also discovered several of the dinosaurs whose fossils were analyzed in the study.

The question of how an animal gets big is a surprisingly tricky one. Mammals like us tend to go through a period of extreme growth when we're young and then stay the same size once we reach adulthood. In other animal groups, that's not always the case. "Growth rate really varies, there's no one size fits all," says Cullen, who is now a postdoctoral

researcher at the North Carolina Museum of Natural Sciences. "Birds have super growth spurts and reach adult size really fast, while reptiles like alligators and various lizards and snakes have extended growth. With them, a really, really big individual is probably really old."

Theropod dinosaurs like *T. rex* are related to both modern birds and reptiles—in fact, birds are the only living theropods. Scientists didn't know whether theropods' growth patterns were more like those of birds or reptiles, and those different growth patterns can make a big difference in how an animal fits into its ecosystem. Getting big quickly can be a competitive advantage—it makes it easier for you to hunt other animals, and harder for other animals to hunt you. On the flip side, a growth spurt takes a lot of energy and resources, and it's easier to just get a little bigger every year your whole life. "The amount of calories *T. rex* would have needed during its growth spurt would have been ridiculous," says Cullen—like a teenage boy that ate dinosaurs instead of endless bags of bagel bites.

The central struggle in studying extinct animals is that we can never know exactly what their lives were like. Since we can't directly observe a dinosaur growing the way you can a living animal today, it's hard to know for sure how they grew. But there are clues in the fossil record that reveal growth patterns.

""Inside the bones as an animal grows, there are markings like tree rings that record roughly how old the animal is, how much it's growing each year, and a number of other factors," says Cullen. To find these growth rings, Cullen and his colleagues sliced into fossils from dozens of dinosaurs, from ones the size of dogs and ostriches all the way up to SUE the *T. rex*, one of the biggest predatory dinosaurs ever discovered. Getting access to slice and dice bones from a range of theropods was not an easy proposition, but Cullen and Makovicky reached out to colleagues across the globe. In particular, they were able to get samples from a new

species of giant carcharodontosaurid from Argentina as a direct counterpoint to *T. rex*—this specimen was discovered and excavated by Makovicky in collaboration with his Argentinean colleagues Juan Canale and Sebastian Apesteguía. The authors also reached out to colleagues at the Palaeontological Museum of Liaoning for samples of small theropods closely related to birds to get the evolutionarily broad sampling needed to determine large scale patterns in life history.

"The very first specimen that the Field Museum let me sample was SUE the *T. rex*," says Cullen. "It was pretty nerve-wracking, since it's such a famous fossil." He used a diamond-tipped coring drill to cut a tiny cylinder out of SUE's thigh bone. The resulting sample was a cross-section of SUE's bone, with lines like tree rings showing where new bone had grown year after year. (The missing piece of bone, about the size of a D battery, was then filled in with brown putty—if you go see SUE at the Field Museum and look closely at their left thigh you might see it, but it's hard to spot.)

Back in the lab, Cullen sliced samples of bone so thin that light could pass through them and examined them under a microscope.

"Most animals have a period every year when they stop growing, traditionally suggested to be in times like winter when food is more scarce. It shows up in the bones as a line, like a tree ring," says Cullen. By analyzing these growth lines and examining the bones for new regions of growth, scientists can get a rough estimate of an animal's age and how much it grew every year. There are also clues in the bone structure.

"You can see all the little areas where the bone cells have grown, and the structure of the blood vessels that passed through the bone," says Cullen. "These vascular canals tell you roughly how fast the bone was growing. If the canals are more organized, the bone was being laid down more slowly, and if the structure is chaotic, it grew more quickly."

Cullen found that the dinosaurs' growth patterns depended on their family. *T. rex* and its relatives, the coelurosaurs, showed a period of extreme growth during adolescence, and then they petered out once they reached adulthood. SUE the *T. rex* lived to be about 33 years old, the oldest *T. rex* currently known, but reached their adult size by age 20. To reach this massive size, SUE probably gained around 35-45 pounds per week as a teenager. Their more distant cousins, the allosauroids, could reach sizes almost as big as *T. rex*, but they grew slowly throughout their whole lives, with the oldest individuals reaching the biggest sizes. Among the allosauroids they sampled was the new carcharodontosaur from Argentina. It reached a size close to that of SUE, but didn't reach adult size until its 30s to 40s. It lived to be up to about 50 years old or more, making it the oldest individual theropod on record aside from some birds like parrots. Despite its advanced age, it had only stopped growing 2 or 3 years before becoming part of the fossil record.

The discovery opens up questions about how these predatory dinosaurs interacted with the animals around them. The plant-eating dinosaurs that lived alongside *T. rex* were ceratopsians like Triceratops and duck-billed hadrosaurs. They grew extremely quickly in adolescence too. The slow-growing allosauroid carnivores lived with big long-necked sauropods that also grew quickly, but appear to have taken a long time to reach full size. Those trends might be related.

"We can't say for sure, but there could be some kind of a selection pressure for the coelurosaurs to grow quickly to keep up with their prey, or pressure for the allosauroids to keep growing in size since their prey were also increasing in size," says Cullen. "But it's pretty speculative. It could be that even if the sauropods kept growing their whole lives, they had so many offspring that there was always something small to eat."

But while the research hasn't answered all the questions about why dinosaurs like *T. rex* grew the way they did, Cullen says, "I'm really

proud of this work. It's the culmination of many, many years of small projects building towards sort of a central goal of trying to understand growth in these animals and understand the many factors that influence these patterns. This doesn't resolve it, but this is a really big step forward."

More information: Osteohistological analyses reveal diverse strategies of theropod dinosaur body-size evolution, *Proceedings of the Royal Society B* (2020). rspb.royalsocietypublishing.or … .1098/rspb.2020.2258

Provided by Field Museum