Ecology & Evolution | May 23, 2026 | 8 min read | By Bryan White

Trading Claws for Jaws: The Real Reason Carnivorous Dinosaurs Evolved Tiny Arms

Biology * Evolution * Animals

The Theropod Forelimb Paradox

Across more than 160 million years of Mesozoic history -- from their Late Triassic emergence until the Cretaceous-Paleogene mass extinction -- non-avian theropod dinosaurs diversified into the dominant bipedal terrestrial carnivores on Earth.[1] Among their most debated morphological features is the extreme reduction of the forelimbs in apex predators such as Tyrannosaurus rex.[1][2] Historically, vertebrate paleontologists framed these diminutive appendages either as passive byproducts of negative allometric scaling relative to gigantic body size or through localized behavioral hypotheses, such as mating claspers or prone-to-standing stabilizers.[2][4]

A comprehensive macroevolutionary study published in May 2026 in Proceedings of the Royal Society B: Biological Sciences by Charlie Roger Scherer and Paul Upchurch (University College London) alongside Elizabeth Steell (University of Cambridge) overturns these passive scaling explanations.[1][2] Analyzing osteological and metric datasets across 82 species of non-avian theropods, the researchers established that forelimb reduction evolved independently via convergent evolution in at least five distinct carnivorous clades.[1][6] Rather than being driven simply by overall body mass, arm reduction was inversely and causally coupled to the evolution of massive, heavily ossified skulls capable of delivering bone-crushing bite forces.[6][7]

Macroecological Drivers and Quantitative Morphometrics

The evolution of reduced theropod forelimbs was closely linked to the Jurassic and Cretaceous proliferation of megaherbivorous sauropods reaching lengths of 30 meters and masses of dozens of tons.[3] While smaller basal theropods relied on elongated, clawed forelimbs to grapple and restrain prey, physically grappling a struggling multi-ton sauropod carried a severe risk of forelimb fracture or dislocation.[1][3] Consequently, natural selection favored apex predators that shifted their primary predatory apparatus entirely to the cranium.[7][8] Phylogenetically, cranial reinforcement preceded forelimb shortening, confirming that the craniomandibular complex first assumed full responsibility for prey dispatch before selective pressure maintaining grasping arms was relaxed and developmental energy was reallocated to cranial and cervical musculature.[8][9]

To test this cranial displacement hypothesis quantitatively across equalized phylogenetic branch lengths (minimum one million years), Scherer et al. paired two comparative indices:[1][10]

* The Cranial Robusticity Score (CRS): Rather than relying solely on skull length -- which can conflate fragile, elongated snouts with crushing jaws -- the CRS

integrates dorsoventral skull compactness, dentition robustness, estimated bite force, and, weighted at double value, the degree of osteological suture fusion across cranial elements.[6][10][11] Complex interdigitating or obliterated sutures distribute chaotic torsional stresses across the cranial vault when biting through bone.[11] Tyrannosaurus rex achieved the highest CRS in the non-avian dinosaur record at 39.2 (~80% of the theoretical maximum), followed closely by the Early Cretaceous carcharodontosaurid Tyrannotitan chubutensis.[6][11]

* The Skull-Forelimb Ratio (SFR): Defined as the ratio of absolute proximodistal skull length to the combined length of the humerus, radius/ulna, and manus.[11] Forelimbs are formally classified as "reduced" at SFR 1.0 and "vestigial" at SFR 1.2, plateauing across 63 complete taxa at an upper limit of 1.6-1.7.[1][11][12]

Across the dataset, taxa with highly robust crania (CRS > 25) consistently exhibited SFR values between 1.1 and 1.7, whereas delicate-skulled or edentulous theropods (CRS of 10-15) rarely exceeded an SFR of 1.1.[11]

Convergent Clades and Divergent Developmental Pathways

Forelimb reduction arose independently across five major theropod clades spanning Gondwana and Laurasia -- Abelisauridae, Carcharodontosauridae, Tyrannosauridae, Ceratosauridae, and Megalosauridae -- yet osteological tracking demonstrates that different clades reached this convergent functional endpoint via distinct evolutionary developmental pathways.[1][8]

| Theropod Clade | | Geologic Temporal Range | | Notable Taxa with Reduced Forelimbs | | General Geographic Distribution |

| Abelisauridae | | Middle Jurassic - Late Cretaceous | | Eoabelisaurus, Carnotaurus, Majungasaurus | | Gondwana (South America, Madagascar, India, Africa) |

| Carcharodontosauridae | | Early Cretaceous - Late Cretaceous | | Tyrannotitan, Meraxes gigas, Acrocanthosaurus | | Gondwana and Laurasia |

| Tyrannosauridae | | Late Cretaceous | | Tyrannosaurus rex, Tarbosaurus, Gorgosaurus | | Laurasia (North America, Asia) |

| Ceratosauridae | | Late Jurassic | | Ceratosaurus | | North America, Europe, Africa |

| Megalosauridae | | Middle Jurassic - Early Cretaceous | | Torvosaurus, Megalosaurus | | Europe, North America |

In Gondwanan Abelisauridae (and similarly in Late Jurassic Ceratosauridae such as the 966-kilogram Ceratosaurus), reduction proceeded via a modular, distal-to-proximal sequence during their Mesozoic adaptive radiation.[1][8][14] The Middle Jurassic basal abelisaurid Eoabelisaurus mefi (~170 Ma, Patagonia) preserved unreduced proximal elements (humerus, radius, ulna) alongside a markedly foreshortened manus.[1][13] By the Late Cretaceous, reduction migrated proximally into the zeugopodium, immobilizing the radiohumeral joint in Carnotaurus (SFR = 1.224) and culminating in the Maastrichtian Madagascar apex predator Majungasaurus crenatissimus (SFR = 1.613).[1][11] Weighing only 750-1,100 kilograms (less than one-fifth of T. rex), Majungasaurus proves that extreme arm vestigialization tracked cranial robusticity rather than super-gigantism.[1][6]

Among Carcharodontosauridae, giant carnivores such as the 6-7.4-tonne Tyrannotitan (118-113 Ma) and the remarkably complete 4-tonne Meraxes gigas (95-90 Ma, Huincul Formation, Patagonia) evolved oversized skulls and vestigial arms (SFR = 1.562 in Meraxes) 20 million years before T. rex.[1][15][16][17] Tellingly, Meraxes and its similarly sized North American relative Acrocanthosaurus exhibit distinct forelimb proportions, confirming that localized cranial and ecological pressures -- not uniform body-mass allometry -- governed reduction.[1]

Conversely, Laurasian Tyrannosauridae underwent synchronous, proportional reduction across all forelimb segments simultaneously.[1] Basal Early Cretaceous tyrannosauroids like Guanlong and Dilong and intermediate Eotyrannus retained slender skulls, three functional digits, and elongated hands (123%-136% of humerus length).[1][18] As Late Cretaceous tyrannosaurines (Daspletosaurus, Gorgosaurus, Tarbosaurus, and T. rex) evolved fused, bone-crushing crania and lost the third digit, the humerus, forearm, and manus shrank in lockstep, reducing the manus-to-humerus ratio to 80% in T. rex.[1][11][18]

| Taxon | | Evolutionary Stage | | Est. Body Length | | Functional Digits | | Manus-to-Humerus Ratio |

| Guanlong | | Early/Basal | | 3 meters | | 3 | | 126% |

| Dilong | | Early/Basal | | 1.6 meters | | 3 | | 123% |

| Eotyrannus | | Intermediate | | 4 meters | | 3 | | 136% |

| Daspletosaurus | | Late/Derived | | 9 meters | | 2 | | 119% |

| Tyrannosaurus rex | | Terminal Apex | | >12 meters | | 2 | | 80% |

Developmental Constraints, Ecological Exceptions, and Secondary Pressures

Despite severe vestigialization, non-avian theropods never lost their forelimbs completely, hitting an anatomical lower bound near a 0.4 forelimb-to-femur ratio.[19] Complete limb loss likely carried lethal pleiotropic costs due to shared embryonic gene regulatory networks.[19] Moreover, healed stress fractures on T. rex humeri indicate that reduced arms still experienced mechanical loading during non-predatory behaviors.[5] Within Late Cretaceous carnivore guilds, secondary selective pressures such as niche assimilation and gregarious carcass feeding also favored compact forelimbs, preventing conspecifics from amputating or fatally maiming exposed arms during feeding frenzies.[20]

Exceptions among giant theropods further validate the cranial displacement model. Multi-ton omnivorous or herbivorous maniraptoriforms like Deinocheirus and Therizinosaurus retained delicate skulls and massive forelimbs to browse vegetation, while piscivorous spinosaurids and slash-clawed megaraptorans relied directly on enlarged manual claws for prey capture -- confirming that forelimbs shrank only when the cranium monopolized predation.[1]

The Signature of Cranial Dominance

The May 2026 comparative analysis of 82 non-avian theropod species resolves a century-old paleontological enigma: the tiny arms of Tyrannosaurus rex, Meraxes

gigas, and Majungasaurus were not passive allometric accidents of gigantism, but convergent adaptations driven by the rise of bone-crushing cranial weaponry.[1][2] Validated by the tight statistical correlation between the Cranial Robusticity Score and the Skull-Forelimb Ratio across five independent lineages, vestigial theropod forelimbs stand as the evolutionary signature of an ecological arms race in which the jaws became the supreme instrument of predation.[1][11]

Updates... (Nov 16, 2026): Replaced third-party Scribd link in Works Cited [28] with the peer-reviewed Historical Biology osteology DOI (doi:10.1080/08912963.2013.861830).

Works Cited

* Scherer, C. R., Steell, E., & Upchurch, P. (May 20, 2026). Drivers and mechanisms of convergent forelimb reduction in non-avian theropod dinosaurs. Proceedings of the Royal Society B: Biological Sciences, 293(2071), 20260528. -- https://doi.org/10.1098/rspb.2026.0528

* ScienceDaily (May 19, 2026). T. rex's tiny arms may have evolved for a surprisingly brutal reason. -- https://www.sciencedaily.com/releases/2026/05/260519224314.htm

* ScienceAlert (May 21, 2026). Scientists May Finally Know Why T. Rex Had Such Tiny Arms. -- https://www.sciencealert.com/scientists-may-finally-know-why-t-rex-had-such-tiny-arms

* BioScience Pakistan (May 20, 2026). Scientists Found The Real Reason T. rex Had Tiny Arms May Have Nothing to Do With Its Size. -- https://www.bioscience.com.pk/en/subject/earth-science/scientists-found-the-real-reason-t-rex-had-tiny-arms-may-have-nothing-to-d

* Wikipedia (2026). Tyrannosaurus. -- https://en.wikipedia.org/wiki/Tyrannosaurus

* University of Cambridge (May 20, 2026). Why meat-eating dinosaurs like T. rex evolved tiny arms. -- https://www.cam.ac.uk/research/news/why-meat-eating-dinosaurs-like-t-rex-evolved-tiny-arms

* Popular Science (May 19, 2026). Why were T. rex's arms so tiny? Paleontologists finally find an answer. -- https://www.popsci.com/science/why-t-rex-arms-tiny/

* Mirage News (May 20, 2026). Why Meat-eating Dinosaurs Like T. Rex Evolved Tiny Arms. -- https://www.miragenews.com/why-meat-eating-dinosaurs-like-t-rex-evolved-1677125/

* Sci.News (May 20, 2026). Mystery of Tyrannosaurus rex's Tiny Arms May Finally Have an Answer. -- https://www.sci.news/paleontology/non-avian-theropod-dinosaur-forelimb-reduction-14781.html

* Scherer, C. R., Steell, E., & Upchurch, P. (May 20, 2026). Drivers and mechanisms of convergent forelimb reduction in non-avian theropod dinosaurs (PubMed record). -- https://pubmed.ncbi.nlm.nih.gov/42156072/

* The Royal Society / Figshare (May 20, 2026). Electronic Supplementary Material from Drivers and mechanisms of convergent forelimb reduction in non-avian theropod dinosaurs. -- https://rs.figshare.com/articles/journal_contribution/Electronic_Supplementary_Material_from_Drivers_and_mechanisms_of_conver

* Brochu, C. A. (Jan 14, 2003). Osteology of Tyrannosaurus rex: Insights from a Nearly Complete Skeleton and High-Resolution Computed Tomographic Analysis of the Skull. Journal of Vertebrate Paleontology. -- https://doi.org/10.2307/3889334

* Pol, D., & Rauhut, O. W. M. (Aug 22, 2012). A Middle Jurassic abelisaurid from Patagonia and the early diversification of theropod dinosaurs. Proceedings of the Royal Society B. -- https://doi.org/10.1098/rspb.2012.0660

* Wikipedia (2026). Eoabelisaurus. -- https://en.wikipedia.org/wiki/Eoabelisaurus

* Canale, J. I., Novas, F. E., & Pol, D. (Jan 8, 2014). Osteology and phylogenetic relationships of Tyrannotitan chubutensis Novas, de Valais, Vickers-Rich and Rich, 2005 (Theropoda: Carcharodontosauridae) from the Lower Cretaceous of Patagonia, Argentina. Historical Biology, 27(1), 1-32. -- https://doi.org/10.1080/08912963.2013.861830

* Canale, J. I., Apestegu a, S., Gallina, P. A., et al. (Jul 1, 2022). New giant carnivorous dinosaur reveals convergent evolutionary trends in theropod arm reduction. Current Biology, 32(14). -- https://doi.org/10.1016/j.cub.2022.05.057

* University of Minnesota Twin Cities (Jul 7, 2022). A new giant dinosaur gives insight into why many prehistoric meat-eaters had such tiny arms. -- https://twin-cities.umn.edu/news-events/new-giant-dinosaur-gives-insight-why-many-prehistoric-meat-eaters-had-such-tiny-arms

* Johnson-Ransom, E., Li, F., et al. (Sep 29, 2023). Comparative cranial biomechanics reveal that Late Cretaceous tyrannosaurids exerted relatively greater bite force than in early-diverging tyrannosauroids. The Anatomical Record. -- https://doi.org/10.1002/ar.25326

* Benson, R. B. J., et al. (Jan 23, 2026). Dental evolution in non-coelurosaur theropods. Italian Journal of Geosciences. -- https://doi.org/10.3301/ijg.2026.14

* Holtz, T. R. (Jun 17, 2021). Theropod guild structure and the tyrannosaurid niche assimilation hypothesis: implications for predatory dinosaur macroecology and ontogeny in later Late Cretaceous Asiamerica. Canadian Journal of Earth Sciences. -- https://doi.org/10.1139/cjes-2020-0174