Growth, development, and the origin of major vertebrate groups

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Abstract:

Bird-line archosaurs (birds and their closest relatives, including non-avian dinosaurs) took over the planet twice in their ~235-million-year history. The first takeover was during the Late Triassic (237–201 Ma), when dinosaurs rose from obscure members of a southern Pangea fauna to becomes the largest, most widespread group of terrestrial vertebrates for the remainder of the Mesozoic. Paradoxically, there were few geographic barriers to dispersal across the supercontinent Pangaea during the Late Triassic. Instead, palaeolatitudinal climate bands, and not modern continental boundaries, have been hypothesized to have controlled faunal biogeography, especially of dinosaurs. Increased sampling can test this prediction: if dinosaurs originated under a biogeography following a global trend of palaeolatitudinal-driven Triassic provincialism, then a faunal assemblage similar to those of South America and India—including the earliest dinosaurs—should be present in Carnian deposits along the same palaeolatitude in south-central Africa. My team and I discovered a new fauna from Zimbabwe (~230 Ma) known from abundant remains which includes Africa’s oldest definitive dinosaurs, including a near-complete (~90%), exceptionally preserved skeleton of a new sauropodomorph dinosaur. This new fauna of Zimbabwe greatly resembles those of the other earliest dinosaur-bearing assemblages, supporting a stereotyped ecological setting for the earliest dinosaurs. The biogeography of the first dinosaurs is correlated with palaeolatitude-linked climatic bands, suggesting this climatic control had a global influence on the initial assembly of modern terrestrial ecosystems.

The second dinosaurian takeover was the evolution of living birds—avian dinosaurs—which remain the most diverse group of vertebrates on land today. Living birds possess a highly derived body plan relative to all other living vertebrates, and the avian pelvis in particular experienced dramatic changes during the transition from early dinosaurs to living birds. This stepwise transformation is well-documented by an excellent fossil record, allowing the progressive sequence of ancestral pelvic states to be observed across the avian stem. However, the evolutionary developmental pattern underlying this transformation is lacking, precluding a holistic account of the origin of avian form. There are clues that the avian pelvis evolved via terminal addition—a controversial mechanism whereby ancestral states shift to derived states during development, resulting in ‘recapitulation’. We tested this hypothesis by integrating embryological imaging techniques to record avian pelvic tissues in three dimensions at early embryonic stages, allowing direct comparison with the fossil record. Many ancestral dinosaurian features are present in the early morphogenesis of birds, which only arrive at their typical ‘avian’ form after transitioning through a developmental sequence that mirrors evolutionary history. The retention of ancestral states in avian development may stem from conserved modular relationships, with covariation of pelvic elements persisting across millions of years of evolution in disparate clades.