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Perspective

The *Archaeopteryx* Point to Active Flight and Communication and Geometry

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DESCRIPTION

Archaeopteryx is a well-known German fossil taxon with feathered wings from the Late Jurassic that plays a crucial role in understanding how birds first learned to fly. It has remained difficult to interpret in a locomotory context despite more than 150 years of research into its mosaic anatomy, which unifies the characteristics of flying birds and non-flying dinosaurs. Three new *Archaeopteryx* specimens from phase-contrast synchrotron microtomography are compared to a sample of archosaurs with a variety of locomotory strategies in this study. According to the findings of our investigations, the architecture of Archaeopteryx's wing bones consistently possesses a combination of cross-sectional geometric properties that are only found in volant birds, particularly those that flake occasionally over short distances. As a result, we conclude that *Archaeopteryx* actively utilized wing flapping to take flight in a manner that was more anterodorsally and posteroventrally oriented than that of modern birds. This unexpected result suggests that powered flight by birds must have existed prior to the most recent Jurassic period.

Due to the scarcity of representative fossil material and the resulting limited phylogenetic resolution, the earliest stages of avian evolution and the development of avian flight remain obscure. *Archaeopteryx*, the oldest known avian with the potential to fly on its own, is the best candidate for figuring out how birds first flew. The question of whether the first flying bird-line dinosaurs took flight on their own remains unanswered, despite the fact that the traditional dichotomy between an arboreal and cursorial origin of avian flight has shifted toward the consideration of intermediate perspectives.

Reliable proxies for inferring the habits of extinct tetrapods are skeletal adaptations that structurally accompany known locomotor modes. Evolutionary selection on the relationship between strength and weight and continuous morphological and structural adaptation to life's biomechanical loading regimes determine the cross-sectional geometry of limb bones. Consequently, the application of beam theory mechanics reveals this stress regime through the avian wing skeleton.

Propagation Phase-Contrast Synchrotron X-Ray Microtomography (PPC-SR-CT) now offers non-destructive alternatives, despite the fact that the value of exceptional and rare fossils discourages physical cross-sectioning. We visualized complete circa mid-diaphyseal humeral and ulnar cross sections of three *Archaeopteryx* specimens using a novel data acquisition protocol and PPC-SR-CT at the European Synchrotron Radiation Facility because these elements exhibit the strongest flight-related biomechanical adaptation in the modern avian brachium. Reconstructed transverse cross-sectional geometry was compared to that of 69 different archosaurian humeri and ulnae representing a wide range of locomotory behaviors. To contrast the conditions of pterosaurian volancy with those of the independently developed avian flight apparatus, we included the basal "long-tailed" pterosaur Rhamphorhynchus and the derived "short-tailed" pterosaur Brasileodactylus in our archosaurian reference set. This was particularly noteworthy. Comparing the pterosaurian and avian flight apparatuses may reveal analogous wing bone geometry adaptations, despite their fundamental morphological differences.

Additionally, we conclude that *Archaeopteryx* used a flight stroke distinct from that of modern birds. Lastly, we discovered that the evolution of short-tailed pterosaurs from primitive long-tailed pterosaurs to more derived short-tailed pterosaurs was accompanied by wing bone geometry changes that were qualitatively comparable to the ones that differentiate *Archaeopteryx* and mostly flapping birds from hyperaerial birds, respectively.

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