January 7, 2021

Evolution & Behaviour

How small warm-blooded feathered flying dinosaurs came to be

by **Enrico L. Rezende**[1] | Associate Professor

doi.org/10.25250/thescbr.brk447

[1]: Center of Applied Ecology and Sustainability (CAPES), Departamento de Ecología, Facultad de Ciencias Biológicas, Pontificia Universidad Católica de Chile

This Break was edited by Ayala Sela, Scientific Editor - TheScienceBreaker

How warm-blooded birds and mammals evolved from cold-blooded ancestors remains a major question in paleontology and evolutionary biology. A heat transfer model suggest that shrinking in size while boosting metabolism is the most efficient evolutionary trajectory on energetic grounds, which seems to explain the reduction in size detected in theropod dinosaurs as they evolved into birds.

Image credits: Enrico L. Rezende

Dinosaurs have fascinated society for ages, or at least since the first specimens were described by Sir Richard Owen in the 19th century. These extinct 'terrible reptiles' supported the evolving world proposed by Darwin, exemplified by the discovery of a fossil in Germany, only two years after the publication of the On the Origin of Species. This extinct creature, named Archaeopteryx, exhibited a transitional form, with reptile-like skeleton and bird-like feathers, and was bought and brought to the Natural History Museum in London by Owen himself. Reconstructing the history of the Archaeopteryx revealed that dinosaurs still live among us - in the form of birds. Surprisingly, in the last two decades it became clear that all birds originated in theropods - a group of bipedal dinosaurs, characterized by having hollow bones and three-toed limbs - whose most famous representatives are the T. rex and the Velociraptor of Spielberg's Jurassic Park.

The theropod evolutionary tree includes these two species, the transitional Archaeopteryx, extinct and surviving bird species. This suggests that as more bird species evolved, fewer dinosaur species survived. The question is why? We hypothesized that the main driver of this was the evolution of higher metabolic rates as theropods became 'warm-blooded'. Endothermy, or the capacity to regulate body temperature employing metabolic heat, allows organisms to remain highly active and colonize cold environments. This interesting evolutionary transition occurred independently in birds and mammals and allowed both groups to thrive. However, these benefits come at a very high energetic cost as metabolic rates of warm-blooded birds and mammals are 5 to 20 times higher than similar-sized cold-blooded vertebrates.

We decided to study this problem from the perspective of cost-benefit: how and when would the benefits of evolving an endothermic machinery outweigh the costs? To answer these questions, we used Newton's law of cooling to calculate the amount of body heat lost to the environment. One of the key factors we considered was body size, because both the rates of heat production and heat loss vary with size. Using this information, we can better evaluate the amount of energy required to transition from cold-blooded to a warm-blooded.

Fossil records of the ancestors of birds show a gradual decrease in body size over time. When using this input in out simulations, we show that this decrease in body size minimized the energy costs of the transition from cold-blooded to warm-blooded. In other words, the costs of being large were traded for the costs of producing heat and being agile. Moreover, our model suggests that being smaller and warm-blooded saves energy, which could allow the population to expand and diversify. This explains how an "expensive" lifestyle can prevail and evolve despite its costs. (As an analogy, a similar trend is currently invoked in the NBA where larger and heavier basketball players are being displaced by leaner and more agile shooters, simply because they win more games).

Our next goal was estimating when this process occurred. By combining our model with fossil records, we were able to reconstruct the evolution of metabolism in theropods and pinpoint a pronounced rise in metabolic rates around 180 million years ago between the Early and Middle Jurassic. Interestingly, during this period the number and variety of theropod species increased drastically, suggesting it was linked to the evolution of warm-blooded theropods. In the lineage leading to birds, specifically, we determined that the order of the key transitions was: the evolution of insulative feathers, then a reduction in size with an increment in metabolism, and then the emergence of flight.

Taken together, these analyses unravel a fascinating history of how dinosaurs and birds have evolved, and a great example of our ever-changing perception and understanding of these groups. From a personal perspective, my collaborators and I can only dream that these results would have pleased Owen, Newton, Darwin and Spielberg (admittedly, Newton was unaware of evolution by natural selection and Owen apparently hated the idea). Regardless of their opinion, however, we are very proud to have contributed to the glorious account of how a T. rex gradually morphed into a chicken.