Change in developmental timing was crucial in the evolutionary shift from dinosaurs to birds: study

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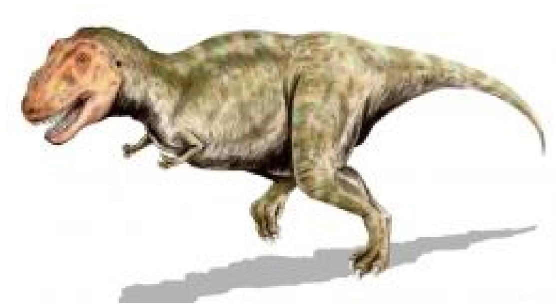

Tyrannosaurus rex. Image: Nobu Tamura, via Wikipedia.

At first glance, it's hard to see how a common house sparrow and a Tyrannosaurus Rex might have anything in common. After all, one is a bird that weighs less than an ounce, and the other is a dinosaur that was the size of a school bus and tipped the scales at more than eight tons.

For all their differences, though, scientists now say that two are more closely related than many believed. A new study, led by Harvard scientists, has shown that modern birds are, essentially, living dinosaurs, with skulls that are remarkably similar to those of their juvenile ancestors.

As reported in a May 27 paper in *Nature*, Arkhat Abzhanov, Associate

Professor of Organismic and Evolutionary Biology and Bhart-Anjan Bhullar, a PhD student in Abzhanov laboratory and the first author of the study, found evidence that the evolution of birds is the result of a drastic change in how dinosaurs developed. Rather than take years to reach sexual maturity, as many dinosaurs did, birds sped up the clock – some species take as little as 12 weeks to mature – allowing them to retain the physical characteristics of baby dinosaurs.

"What is interesting about this research is the way it illustrates evolution as a developmental phenomenon," Abzhanov said. "By changing the developmental biology in early species, nature has produced the modern bird – an entirely new creature – and one that, with approximately 10,000 species, is today the most successful group of land vertebrates on the planet."

"The evolution of the many characteristics of birds – things like feathers, flight, and wishbones – has traditionally been a difficult problem for biologists," Mark Norell, chair of the Division of Paleontology at the American Museum of Natural History and one of the paper's co-authors, said. "By analyzing fossil evidence from skeletons, eggs, and soft tissue of bird-like dinosaurs and primitive birds, we've learned that birds are living theropod dinosaurs, a group of carnivorous animals that include *Velociraptor*. This new work advances our knowledge by providing a powerful example of how developmental changes played a major role in the origin and evolution of birds."

While it's clear simply from looking at the skulls of dinosaurs and modern birds that the two creatures are vastly different – dinosaurs have distinctively long snouts and mouths bristling with teeth, while birds have proportionally larger eyes and brains – it was the realization that skulls of modern birds and juvenile dinosaurs show a surprising degree of similarity that sparked the study.

"No one had told the big story of the evolution of the bird head before," Bhullar said. "There had been a number of smaller studies that focused on particular points of the anatomy, but no one had looked at the entire picture. What's interesting is that when you do that, you see the origins of the features that make the bird head special lie deep in the history of the evolution of Archosaurs, a group of animals that were the dominant, meat-eating animals for millions of years."

To tackle the problem, the researchers turned to an unusual methodology. Using CT scanners, they scanned dozens of skulls, ranging from modern birds to theropods – the dinosaurs most closely related to birds – to early dinosaur species. By marking various "landmarks" – such as the orbits, cranial cavity and other bones in the skull – on each scan, researchers were able to track how the skull changed shape over millions of years.

"We examined skulls from the entire lineage that gave rise to modern birds," Abzhanov said. "We looked back approximately 250 million years, to the Archosaurs, the group which gave rise to crocodiles and alligators as well as modern birds. Our goal was to look at these skulls to see how they changed, and try to understand what actually happened during the evolution of the bird skull."

What Abzhanov and colleagues found was surprising – while early dinosaurs, even those closely related to modern birds, undergo vast morphological changes as they mature, the skulls of juvenile and adult birds remain remarkably similar.

"This phenomenon, where a change in the developmental timing of a creature produces morphological changes is called heterochrony, and paedomorphosis is one example of it," Abzhanov explained. "In the case of birds, we can see that the adults of a species look increasingly like the juveniles of their ancestors."

In the case of modern birds, he said, the change is the result of a process known as progenesis, which causes an animal to reach sexual maturity earlier. Unlike their dinosaurian ancestors, modern birds take dramatically less time – just 12 weeks in some species – to reach maturity, allowing birds to retain the characteristics of their juvenile ancestors into adulthood.

"This study is a prime example of the heuristic power in multidisciplinary, specimen-based, anatomical research," said Gabe Bever of NYIT's New York College of Osteopathic Medicine and a co-author of the paper. "That the mechanisms of evolutionary events millions of years old can be circumscribed with this combination of modern and fossil specimens is remarkable."

Ultimately, Abzhanov said, the way the bird skull evolved – through changes in the developmental timeline – highlights the diversity of evolutionary strategies that have been used over millions of years.

"That you can have such dramatic success simply by changing the relative timing of events in a creature's development is remarkable," he said. "We now understand the relationship between birds and dinosaurs that much better, and we can say that, when we look at birds, we are actually looking at juvenile dinosaurs."

"It shows that there's so much for evolution to act upon," Bhullar agreed. "When we think of an organism, especially a complex organism, we often think of it as a static entity, but to really study something you have to look at its whole existence, and understand that one portion of its life can be parceled out and made into the entire lifespan of a new, and in this case, radically successful organism."

Provided by Harvard University