How dinosaur arms turned into bird wings

September 30 2014

Although we now appreciate that birds evolved from a branch of the dinosaur family tree, a crucial adaptation for flight has continued to puzzle evolutionary biologists. During the millions of years that elapsed, wrists went from straight to bent and hyperflexible, allowing birds to fold their wings neatly against their bodies when not flying.

How this happened has been the subject of much debate, with substantial disagreement between developmental biologists, who study how the wings of modern birds develop in the growing embryo, and palaeontologists who study the bones of dinosaurs and early birds. A resolution to this impasse is now provided by an exciting new study publishing on September 30 in *PLOS Biology*.

Underlying this striking evolutionary transformation change is a halving in the number of wrist bones, but developmental biologists and palaeontologists have different names for most of them, and seldom agree on the correspondence between specific dinosaur bones and those of their bird descendants. Indeed, each field has radically different data sources, methods, and research objectives, talking little to each other.

The critical advance made in the new study involved combining these two strands of research. Using an interdisciplinary approach, the lab run by Alexander Vargas at the University of Chile has re-examined fossils stored at several museum collections, while at the same time collecting new developmental data from seven different species of modern birds. Joao Botelho, a Brazilian student in Vargas' lab, developed a revolutionary new technique that allows him to study specific proteins in

3D embryonic skeletons. By combining these data from both fossils and embryos, the research team has made a major step forward in clarifying how the bird wrist evolved.

From early dinosaur ancestors with as many as nine wrist bones, birds have only kept four during the course of evolution, but which of the original bones are they? The identity of each of these bones was debated. For instance, the late Yale professor John Ostrom famously pointed out in the 1970's that the wrists of both birds and bird-like dinosaurs possess a very similar, half-moon shaped bone called the semilunate, and that this bone resulted from the merging of two bones present in dinosaurs. This formed part of Ostrom's then-controversial argument that birds descended from dinosaurs. However, the failure of developmental biologists to confirm this raised doubts that it was the same bone, and even that birds came from dinosaurs.

Now, the new data obtained by the Vargas lab has revealed the first developmental evidence that the bird semilunate was formed by the fusion of the two dinosaur bones. They go on to show that another bone – the pisiform – was lost in bird-like dinosaurs, but then re-acquired in the early evolution of birds, probably as an adaptation for flight, where it allows transmission of force on the downstroke while restricting flexibility on the upstroke. Combined, the fossil and developmental data provide a compelling scenario for a rare case of evolutionary reversal.

The study by the Vargas lab also settled the identity of the other two bones of the bird wrist, which were commonly misidentified in both fields. This emphasizes the downsides of not integrating all data sources, and reveals a situation perhaps akin to that of astronomy and experimental physics in the pursuit of cosmology: Together, palaeontology and development can come much closer to telling the whole story of evolution – this integrative approach resolves previous disparities that have challenged the support for the dinosaur-bird link

and reveals previously undetected processes, including loss of bones, fusion of bones, and re-evolution of a transiently lost bone.

More information: Botelho JF, Ossa-Fuentes L, Soto-Acuña S, Smith-Paredes D, Nuñez-León D, et al. (2014) New Developmental Evidence Clarifies the Evolution of Wrist Bones in the Dinosaur–Bird Transition. *PLoS Biol* 12(9): e1001957. DOI: 10.1371/journal.pbio.1001957