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*Nature* Editorial

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Dear Editor,

We are writing to submit the manuscript entitled“The consequences of cranial integration on adaptive radiation of birds” as a Letter to Nature. The text is 1791 words and contains three figures and a table. We also have an Extended Online Data including 10 displays and captions, and Supplementary Information comprising an online text file, six figures and eight tables.

*Scientific impact*:

Bird beaks have long been considered as representative of feeding ecology and a classic example of evolutionary independence (modularity) of biological structures facilitating adaptive evolution. Few examples are more iconic and relatable than observations of beak shape and feeding ecology in Galapagos finches, central to Darwin’s development of the theory of natural selection. This long-standing truism has recently been challenged. On a macroevolutionary scale, the bird skull appears modular and the beak can flexibly adapt, yet at a clade level, strong interdependence between the beak and the braincase (integration) has been found in some groups. Furthermore, the link between feeding ecology and beak shape may be weaker than expected in all but highly specialised clades. These studies offer a glimpse of the process of adaptation and diversification, and hint that integration may play a role. Despite this, the prevailing mindset is still that the bird beak is modular, and flexibly adapts independently to the rest of the skull.

Using a sample of 436 bird species across virtually all families of landbirds (Inopinaves) and state-of-the-art geometric morphometrics and phylogenetic comparative methods, we quantify interdependence between the bird beak and braincase in every avian lineage to test whether this condition promotes or constrains evolution. We find high levels of integration across most clades of landbirds. Even more surprisingly, we find that the two textbook examples of adaptive radiations in birds, Galapagos finches and Hawaiian honeycreepers, rapidly evolved a large range of beak shapes despite tight integration between the beak and the braincase. This is highly unexpected. We show that, contrary to conventional thinking, tight integration of the beak and braincase actually facilitated, rather than constrained, diversification in two of the archetypal examples of adaptive radiation.

*Broader Impact*: The results of this paper are of central importance to those interested in evolution and ecology: evolutionary biologists, ecologists, vertebrate anatomists, and developmental biologists. Understanding the mechanisms that underlie why some organisms are more diverse than others in modern ecosystems has wide appeal across, and beyond, science professionals. Our study adds critical new evidence to this debate. Furthermore, the evolutionary model that we propose for cranial evolution in these birds addresses a long-standing question in evolutionary biology and ecology first recognized by Darwin himself: why Darwin’s finches and Hawaiian honeycreepers radiated so much, whilst other birds that colonised the same archipelagos at similar times have depauperate diversities. Furthermore, our methodological implementation will be useful for researchers using high dimensional data in a plethora of disciplines.

Thank you for your consideration.

As potential reviewers we suggest: P. David Polly and Daniel J. Field. P. David Polly is a world-renowned authority in the fields of geometric morphometrics and phylogenetic comparative methods and he has extensively worked in craniofacial evolution in vertebrates. Daniel J. Field is an evolutionary ornithologist whose integrative work has focused on deciphering broad patterns of evolution in birds, including the early evolution of the beak.

Ryan Felice and Anjali Goswami are both good potential reviewers whose work is also relevant to our study, however, they use very different methods which are hardly comparable to ours. Additionally, we suggest not sending the manuscript to Arkhat Abzhanov as he is currently working on very similar questions and he might have a strong conflict of interest.

On behalf of the authors,

**Guillermo Navalón**

**Professor Emily J. Rayfield**