Multiphase progenetic development shaped the brain of flying archosaurs

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Archosaurs is one of the vertebrate group with the longest history and the oldest origin. Through their long evolutionary history, they developed a large variability of size, morphological features and locomotion behaviours. Flight is a particular behaviour that has been developed twice independently by archosaurs during their evolution. As a complex locomotory behaviour, flight requires advanced cognitive capabilities in order to deal with all the information necessary for a proper locomotion. As the center of processing of information and selection of appropriate response, brain is an important structure to study in order to understand how cerebral capacities in archosaurs evolved in parallel of flight evolution. Because of its position at the root of birds, *Archaeopteryx* from the Jurassic of Germany, is a very important taxon as it is considered as the oldest form having developed active flight capabilities in the avian lineage. The study of the features showed the different *Archaeopteryx* specimens add information on how flight capabilities evolved in birds. Another important point of this evolutionary history is the mechanism leading to the appearance of cerebral features related to flight. In this respect, *Haslzkaraptor escuillei*, a small dromaeosaur from the Cretaceous of Mongolia, is a key specimen, showing brain characters very similar to *Archaeopteryx*, despite the fact that it was clearly not a flying animal and probably not having flying ancestors.

Along archosaurs evolution toward flying forms, endocasts show an increase of coiling as well as of infilling level by the brain itself. Basal archosaurs such as crocodiles show an elongated and low-filled endocast, reflecting the primitive condition observed in lepidosaurian. Non-maniraptoriform dinosaurs and then Maniraptoriforms show two successive events of coiling increase, but only small maniraptoriforms suggest an increase of infilling. In crocodiles and non-maniraptoriforms dinosaurs, coiling and low infilling are independent from body size, contrary to maniraptoriforms for which small specimens do present a higher filling level than large sized specimen, for similar coiling values. Finally, birds show a total decoupling of those two characters and size. This general pattern is observed during crocodilian embryonic development, for which coiling and infilling decrease along ontogeny. This suggest a serie of progenetic events, associated with a general size reduction, along archosaurs lineages toward flying forms which was leading to cerebral shape unlocking the cerebral capabilities for flight in birds and pterosaurs.