Key innovations and evolutionary constraints during the evolution of avian flight

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2 authors:

Loredana Macaluso
Università degli Studi di Torino

Emanuel Tschopp
American Museum of Natural History

mammaliaform fossils are the consequence of the labile chondrogenesis of the otic capsule relative to the cochlear nerve(s) and its cochlear ganglion, which also contributed to the varying degrees of the cochlear canal curvature and coiling among different mammalian clades. Both the evolutionary homoplasy and the labile development of osteological structures are deeply rooted in the complex cascade of genetic networks for cochlear development. However, the homoplastic patterns of the cochleas in Mesozoic mammaliaforms provide the historical evidence of how and where along the phylogenies the conserved morphogenetic mechanisms, although highly canalized in normal development of extant mammals, had occurred in much broader variation in the deep evolutionary history of mammaliaforms.

Poster Session I (Wednesday, October 26, 2016, 4:15–6:15 PM)

MARTES AMERICANA IS SELECTIVE IN FOLLOWING THE RULES: A TEST OF BERGMANN'S AND ALLEN'S RULES

LYNCH, Leigha M., Oklahoma State University Center for Health Sciences, Tulsa, OK, United States of America

Martes americana is widely distributed across North America and is successful in many different climates. Wide geographic spread can often result in morphological variation between populations, including differences consistent with Bergmann's or Allen's rule. I tested for both rules in *M. americana* using skeletal measurements from 22 individuals from Alaska (n = 11), Maine (n = 5), Idaho (n = 2), and New York (n = 4).

Bergmann's rule states that individuals of a species living in colder climates will be larger than individuals found in warmer climates. I tested for Bergmann's rule using a Wilcoxon signed-rank analysis on the skull length, as a proxy for body size, of individuals from two groups: 1) Alaska and 2) Maine, Idaho, and New York. These groups are based on the minimum annual temperature of each region, of which Alaska is about 15°F colder. There was a significant difference in skull length between the two groups ($Z = -2.101$, $p = 0.035$), with Alaskan specimens averaging 5 mm larger ($\delta = 0.478$cm) or about 5% of the skull length. This is consistent with Bergmann's rule.

Allen's rule states that individuals living in colder climates will have proportionally shorter limbs than their warm climate counterparts. Because *M. americana* follows Bergmann's rule, I tested whether skull length and limb length were changing in conjunction using a Pearson's correlation. I measured forelimb length by combining the length of the humerus and ulna and hindlimb length by combining the femur and tibia. Both forelimb ($r = 0.704$, $p = 0.001$) and hind limb ($r = 0.746$, $p = 0.0001$) length had a strong and significant positive correlation to skull length. I then tested if this correlation differed between the previous two groups using a Wilcoxon signed-rank analysis for forelimb/skull length and hind limb/skull length. There was significant difference between groups in the forelimb ($Z = 2.445$, $p = 0.014$, $\delta = 0.122$) and hind limb ($Z = 2.781$, $p = 0.005$, $\delta = 0.104$). However, this difference is a result of individuals in Alaska having proportionally longer limbs than similarly sized individuals in warmer regions. For example, an individual from Alaska with a skull length of 8.74 cm has a forelimb and hind limb length about 1 cm longer than an individual with a similar skull length from Idaho. This is the reverse relationship to that proposed by Allen's rule.

The presence of size and limb proportional differences in populations of *M. americana* suggests it is skeletally adapted to a wide climatic range. Future geometric morphometric studies of *Martes* must take allometric effects of shape into account.

Poster Session IV (Friday, October 28, 2016, 4:15–6:15 PM)

ANATOMICAL COMPARISON OF THE POSTCRANIAL SKELETON OF THE EXTANT RED PANDA, *AILURUS FULGENS*, TO THE EXTINCT LATE MIOCENE AILURIDS *SIMOCYON BATALLERI* AND *PRISTINAILURUS BRISTOLI* (CARNIVORA, AILURIDAE)

LYON, Lauren M., East Tennessee State University, Johnson City, TN, United States of America; WALLACE, Steven C., East Tennessee State Univ, Johnson City, TN, United States of America; SALESA, Manuel J., Faculdade de Ciências da Universidade de Lisboa, Lisbon, Portugal; SILICEO, Gema, Universidad de Alcalá, Madrid, Spain; ANTON, Mauricio, Museo Nacional de Ciencias Naturales-CSIC, Madrid, Spain

Pristinailurus bristoli is only known from the late Hemphillian Gray Fossil Site (Washington County, TN). Since its description in 2004 based on an isolated M1, several specimens have been found, bringing the MNI up to seven. Among the new material are two nearly complete specimens: ETMNH 3596 (~98% complete) and ETMNH 15000 (~75% complete). Though being among the most complete known fossil ailurids, both skeletons have yet to be described in detail. Once a widespread and successful group across the northern hemisphere, ailurids are restricted to a single extant taxon (*Ailurus fulgens*) that inhabits the remote regions of the Himalayas. What adaptations did this family exhibit in the past that allowed it to be so successful compared to today? Postcranial fossils of ailurids are rare, so the new material of *P. bristoli*, considered an Ailurinae along with *A. fulgens*, allows direct morphological comparison to address this question. Hence, we compare both ailurines (*P. bristoli* and *A. fulgens*) to the basal ailurid *Simocyon batalleri* from the late Miocene site of Batallones-1 (Madrid, Spain). By including other extant musteloids, we hope to infer if *P. bristoli* was more terrestrial, yet adapted for explosive climbing, as is predicted for *S. batalleri*; more arboreal, like *A. fulgens*; or some ecomorph as yet to be recognized. Initial observations show that some elements of *P. bristoli* are more similar to those of *S. batalleri* in shape, whereas others resemble *A. fulgens*, suggesting that *P. bristoli* was intermediate in morphology, but in a mosaic fashion.

A notable example is the scapula of *S. batalleri*, which exhibits a large surface along the ventro-caudal edge for the teres major. This surface is caudally penetrated by a triangular-shaped wedge that anchors the subscapularis minor (homologous to the postscapular fossa of ursids and amphicyonids). Though incomplete, both scapulae of *P. bristoli* show these features; however, their size cannot be assessed. Such a structure indicates a strong subscapularis minor and teres major, the latter important for vertical movements during rapid climbing, suggesting relatively stronger shoulder muscles and a locomotor behavior different from *A. fulgens*. All of this suggests that there is no clear-cut ailurine or simocyonine postcranial pattern, and that basal ailurines such as *P. bristoli* shared many postcranial characters with simocyonines.

Poster Session II (Thursday, October 27, 2016, 4:15–6:15 PM)

KEY INNOVATIONS AND EVOLUTIONARY CONSTRAINTS DURING THE EVOLUTION OF AVIAN FLIGHT

MACALUSO, Loredana, Università di Torino, Torino, Italy; TSCHOPP, Emanuel, Università di Torino, Torino, Italy

The evolution of powered flight happened three times independently in vertebrates (bats, pterosaurs, and birds). Among these, avian flight is unique in the inclusion of the tail into the forelimb locomotor module. In birds, the shortened tail is connected to a retroverted pubis through the internal and external pubocaudalis muscles. These muscles contribute to tail movements that stabilize the bird during take-off and help maneuvering during flight. Pubis retroversion was thus a crucial innovation during the evolution of avian flight, but it remains unclear how and why this change in orientation occurred at the first place. Retroverted pubes evolved five times convergently among dinosaurs: four times in Maniraptora and once in Ornithischia. Here, we perform Fisher's and Barnard's exact tests to check for statistically significant correlations with traits that possibly influenced the orientation of the pubis: accessory ventilation system, gait, feeding strategy. These tests showed a strong correlation between anteriorly projecting pubes and the presence of the so-called cuirassal ventilation. This accessory ventilation system is considered a plesiomorphic feature within Dinosauria. Cuirassal ventilation helped inflating the lungs through the expansion of the gastral basket by the ischiotruncus muscle, which connected the gastralia to the anteriorly projecting pubis. The correlation indicates that the presence of cuirassal ventilation has been an evolutionary constraint inhibiting pubic retroversion. Within Maniraptora, the evolution of avian ventilation aided by uncinate processes and powered by the external oblique and the appendicocostalis muscles released this constraint and led to the development of the typical avian bauplan necessary for active flight. The acquisition of the avian accessory ventilation was therefore the evolutionary key innovation that allowed a retroversion of the pubis and finally actively powered flight in birds.

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Poster Session II (Thursday, October 27, 2016, 4:15–6:15 PM)

THE EARLY PERMIAN (CISURALIAN) RICHARDS SPUR LOCALITY, OKLAHOMA, USA, AND THE EARLY EVOLUTION AND DIVERSITY OF PARAREPTILIA.

MACDOUGALL, Mark J., University of Toronto Mississauga, Mississauga, ON, Canada; REISZ, Robert R., University of Toronto Mississauga, Mississauga, ON, Canada

Parareptiles first appear in the fossil record in the Late Carboniferous, and the clade continued to diversify into the Permian, eventually obtaining a cosmopolitan distribution and becoming a common component of Middle and Late Permian terrestrial vertebrate faunas. In contrast to their diversity during the Middle and Late Permian, Early Permian parareptiles were historically rare and exhibited low taxonomic diversity, with eureptiles and synapsids being the more common amniote carnivores and herbivores. As a result of extensive studies of the vertebrate assemblage at the Early Permian (289 ma) Richards Spur locality of Oklahoma, several new parareptile species have been described from the locality since the description of *Colobomycter pholeter*, the first parareptile to be found at the locality. These new discoveries have drastically increased our knowledge of parareptile evolution during the Early Permian. Nearly a century of work at this locality has yielded an exceptionally diverse fauna of terrestrial amniotes. The locality represents a unique upland faunal assemblage in which numerous small to medium sized taxa are exceptionally preserved and in abundance.

Here we discuss the importance of the Richards Spur parareptile fauna and how it grants us previously unavailable knowledge of the Early Permian. Currently, eight of the 15 Early Permian described parareptile species are known from Richards Spur. Furthermore, the species present at Richards Spur represent some of the earliest members of most major Early Permian parareptilian clades, the sole exception being the aquatic, Gondwanan-restricted Mesosauridae. These factors indicate that Richards Spur was clearly an important locality for understanding early evolution and diversification of parareptiles. The species-level/taxonomic diversity of Early Permian parareptiles is now coming close to matching that of contemporaneous eureptiles, which is not surprising, given their relationship as sister taxa. The Richards Spur assemblage provides a rare glimpse into the initial diversification of Parareptilia and highlights the importance of this region of Laurasia as the potential center for the radiation of small, predatory parareptiles, as exemplified by the lanthanosuchoids.

Technical Session I (Wednesday, October 26, 2016, 10:30 AM)

HORSES IN THE CLOUD: BIG DATA EXPLORATION, MINING, AND INTEGRATION FOR *EQUUS* (MAMMALIA, EQUIDAE)

MACFADDEN, Bruce J., University of Florida, Gainesville, FL, United States of America; GURALNICK, Robert J., University of Florida, Gainesville, FL, United States of America

Large cloud-based specimen and related natural history databases are becoming more important to analyze biodiversity distributions. Here we report the results of a meta-research study using *Equus*. Extinct species of *Equus* are widely distributed and have an abundant fossil record. Likewise, extant species of the genus *Equus* have a widespread distribution today on all continents except Antarctica. In order to test the efficacy of six relevant big databases for (paleo)biogeographic analyses, location data records (latitude, longitude) for the genus *Equus* were explored and mined from iDigBio, the Paleobiology Database, VertNet, BISON, Neotoma, and GBIF. These were chosen from prior knowledge of where relevant data might be aggregated, and also because these databases have different objectives and data sources and, therefore, would provide a useful comparative study of a widespread taxon. Although they vary based on their objectives, each of the six big databases contain paleontological location data, whereas five contain modern location data as well.

The mining of data records for *Equus* from these six sources yielded 105 thousand location records, ranging from 32.3 thousand (GBIF) to 0.2 thousand (Neotoma). These data include individual points that are unique, in other words, only occurring in one of