Synchrotron X-ray imaging enables 3D quantification of bone microstructures across fossil and modern bird-line archosaurs

D. F. A. E. Voeten[1,2], P. Tafforeau[2], and S. Sanchez[1,2]

[1]Uppsala University, Subdepartment of Evolution and Development, Department of Organismal Biology, Evolutionary Biology Centre, Norbyvägen 18A, 752 36 Uppsala, Sweden. [2]European Synchrotron Radiation Facility, 71 Avenue des Martyrs, CS-40220, 38043 Grenoble Cedex, France. **dennis.voeten01@upol.cz**

The origin and early establishment of feathered flight (> 150 million years ago) ultimately allowed one group of dinosaurs to negotiate the end-Mesozoic mass extinction event (~ 66 million years ago). Although early birds diversified into the most speciose living tetrapod clade, many crucial evolutionary adaptations to early dinosaurian flight remain unresolved.

Fossilised bone represents a valuable archive that not only recorded macromorphological adaptations, but also registered microstructural indicators for life history, metabolic activity, and biomechanical optimisation. Osteohistological thin sectioning still grants unparalleled resolution, colour information, and cross-polarised details. However, destructive sampling prevents inclusion of high-profile fossils and microscopic slides only cover a limited depth.

We sampled a representative assemblage of fossil and modern archosaurs with propagation phase-contrast synchrotron X-ray micro-computed tomography, which is nondestructive, at the beamlines BM05, ID17, and ID19 of the ESRF. Vascular infrastructures that evolved under the influence of niche-specific physiological constraints were visualised in 3D. Their orientation was quantitatively characterised along the avian ancestry (**Fig. 1**) to identify structural signatures associated with archosaurian physiological and locomotory flexibility.

Ongoing improvement of the ESRF synchrotron, including implementation of the Extremely Brilliant Source, continues to expand the possibilities for nondestructive visualisation of materials. The new beamline BM18 will fuel innovative applications for high-energy, hierarchical multi-scale imaging of most fossil tissues and materials. In this context, our example not only offers insight into bone structural adaptations to archosaurian flight but will also serve future (palaeo-) biological and material science studies.

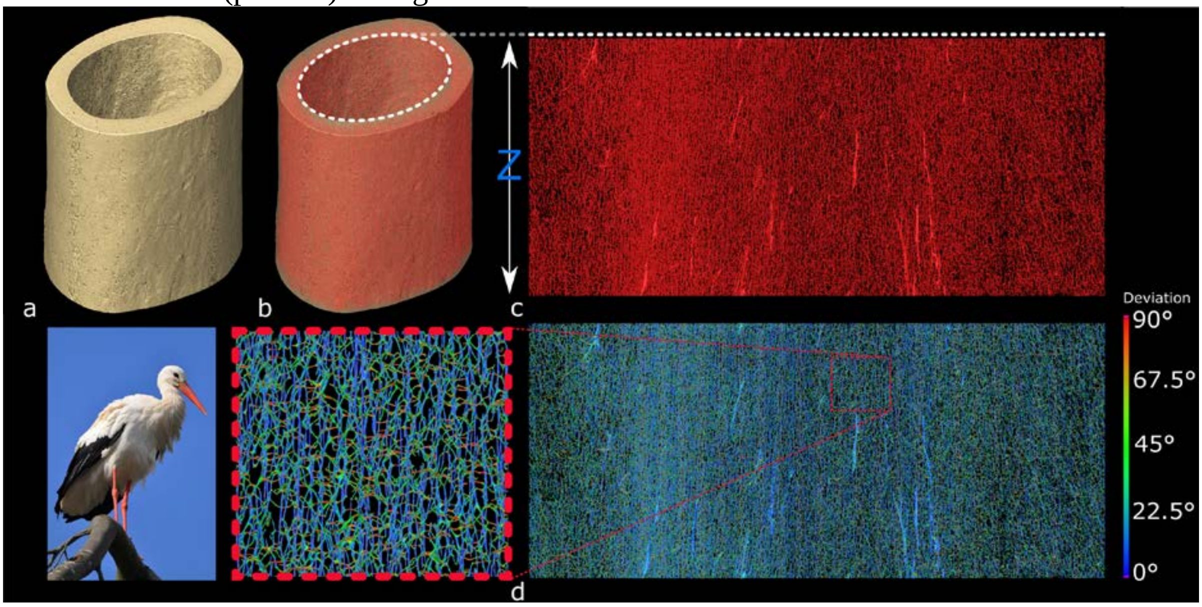

Figure 1: The ulnar mid-diaphysis (a) of the stork *Ciconia ciconia* and its vascular mesh (b). We virtually 'unrolled' the vascular mesh (c) and visualised and quantified local deviations from the bone long axis (d).