Endless forms most beautiful: the evolution of skeletal diversity and complexity in tetrapod animals

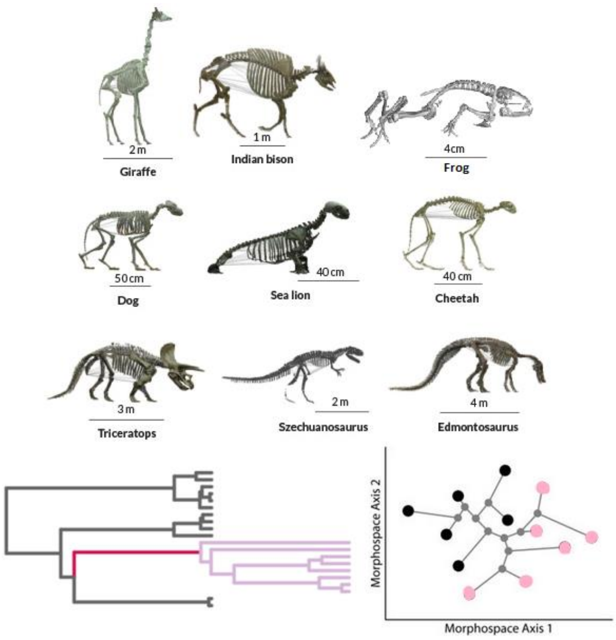
Keywords: macroevolution, tetrapod, disparity, morphology, palaeobiology, evolutionary rates, morphospace, skeleton, body plan

Principle Supervisor: **Dr Tom Stubbs** – Lecturer in Biology, School of Life, Health and Chemical Sciences, thomas.stubbs@open.ac.uk

Co-Supervisor: **Dr Luke Mander** – Senior Lecturer in Earth Sciences, School of Environment, Earth and Ecosystem Sciences, luke.mander@open.ac.uk

Tetrapod animals have incredible biodiversity, represented by all living amphibians, mammals, reptiles and birds, and all their extinct representatives back to the Late Devonian ~365 million years ago. This biodiversity is reflected by both huge species numbers and exceptional variation in morphology and ecology; everything from frogs to dinosaurs!

All tetrapods share a basic body plan and many of the same structural skeletal components; typically consisting of a head, neck, thorax, limbs, girdles, and tail. Evolutionary processes acting on these components drive body plan diversity, or 'morphological disparity'. The origins and expansions of major groups often involve major body plan innovation as groups expand into new ecological spaces, such as flight in birds, or aquatic transitions like in whales.



Sample of skeletal body plan disparity in tetrapod animals (Images from Clauss et al. 2016). Also figured are schematic illustrations of evolutionary rate variation and morphospace distribution.

Many important questions remain about the evolution of skeletal diversity and complexity in tetrapods, both through geological time and across the Tree of Life. This project aims to quantify the skeletal diversity of all living and extinct tetrapod animals in a unifying morphological space ('morphospace') and phylogenetic framework. We can then answer many questions about the importance of evolutionary radiations and extinction events, and the roles of potential triggers such as environmental conditions or genomic controls. For example, which tetrapod groups show greatest body plan variation, and is this linked with high taxonomic diversity or ecological dominance? Do certain groups evolve faster, with more dynamic evolutionary histories? When, in geological time, did tetrapods achieve their full range of forms, and how does this compare to modern times? Are some areas of morphospace saturated, and what do these forms represent?

This project aims to answer these questions, and to understand and quantify the processes behind the diversity of tetrapod body plans, with an emphasis on evolutionary flexibility, disparity, directionality, and tempo. This will be achieved by sampling all tetrapod families and using a combination of morphometric techniques and phylogenetic comparative methods. Skeletal disparity will be quantified with anatomical network analysis (e.g. Esteve-Altava *et al.* 2019), geometric morphometrics (e.g. Maher *et al.* 2022) and traditional morphometrics (e.g. Gutarra *et al.* 2023). Disparity will then be analysed in a phylogenetic framework examining rate variation (e.g. Stubbs *et al*. 2021) and changes to evolutionary landscapes incorporating directional changes and cases of significantly increased disparity (Pagel *et al*. 2022).

An important component of this project is training in advanced computational skills and high-performance computing, including R coding and specimen digitization. These skills will be widely applicable in future research or in many data science careers outside academia. You will also develop skills in comparative anatomy, presentation skills at national/international conferences, and will lead and contribute to peer-reviewed publications. There will be opportunities for continued professional development and training in transferable skills throughout the program.

This project would be well suited to a student who has an undergraduate degree or master's in biology, zoology, palaeobiology or the biological applications of computer science.

For informal enquiries, please contact Dr Tom Stubbs (thomas.stubbs@open.ac.uk).

References

Clauss et al (2016) Journal of Anatomy 230, 325-336. https://doi.org/10.1111/joa.12557

Esteve-Altava, B. et al (2019) Science Advances 5, eaau7459. 10.1126/sciadv.aau7459

Gutarra, S. et al (2023) Palaeontology 66, e12645. https://doi.org/10.1111/pala.12645

Maher, A. et al (2022) Nature Communications 13, 4340. https://doi.org/10.1038/s41467-022-32028-2

Pagel et al (2022) Nature Communications 13, 1113. https://doi.org/10.1038/s41467-022-28595-z

Stubbs et al (2021) Proceedings of the Royal Society B 288, 20210069. https://doi.org/10.1098/rspb.2021.0069