The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

Disentangling the dynamics of diversification in deep time

Supervisory Team	• **Erin Saupe** https://www.earth.ox.ac.uk/people/erin-saupe/ • **Roger Benson** https://www.earth.ox.ac.uk/people/roger-benson/

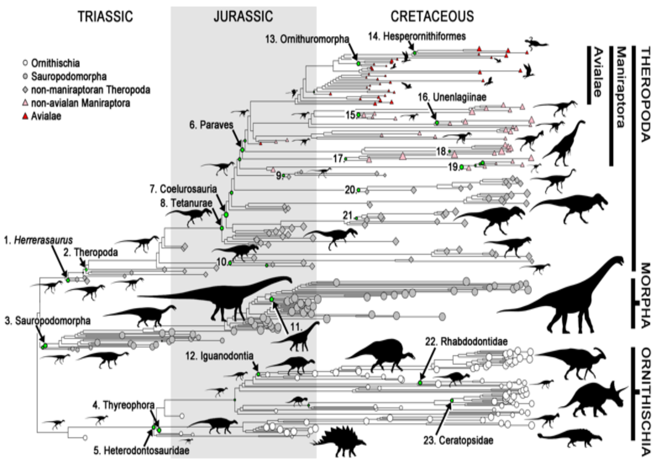
Key Words	**Palaeobiology, diversification, turnover, macroevolution**

Overview

How did the enormous diversity of extant species come to be? The dynamics of species diversification on extended, geological timescales are highly uncertain. Is diversification a continuous and unbounded process, or is there evidence that ecological limits have regulated the accumulation of species richness? Are there pulses of turnover? If so, on what scales do they occur, and are they associated with changes in species richness, or just species identities? There is currently no consensus (e.g. Harmon & Harrison 2015; Rabosky & Hurlbert 2015), and a general theory of diversification across time, space, and environments remains elusive.

Two sources of data are particularly relevant to these questions. The fossil record provides evidence of species appearances and disappearances through time (Sepkoski 1984), but has mainly been studied on coarse timescales. Phylogenies, predominantly of extant species, preserve the signature of historical dynamics in their topologies and branch lengths (Felsenstein 1985; Webster et al. 2003), but are pruned by non-random extinctions, limiting their temporal scope. Much of the current uncertainty on questions of diversification might result from the disconnect between timescales embodied by studies of these two sources of information.

This project will make use of high-resolution fossil record databases to examine the dynamics of speciation and extinction, and how they vary with temporal scale of study. These will form the basis of simulations, using birth-death models to grow phylogenies according to empirical patterns of variation observed among fossils. For example, by varying the frequency, severity, and clade-selectivity of extinction pulses. Comparison to real phylogenies will establish the importance of this variation in the diversification of life on Earth.



Phylogenetic hypothesis for the evolution of dinosaurs and their body mass, from Benson et al. (2014) Plos Biology.

Methodology

This project will involve simulations of birth-death processes under a variety of extinction and speciation scenarios, quantitative analysis of spatio-temporal fossil occurrence data, and literature surveys of extant and fossil clade dynamics.

Timeline

Year 1: Statistical training courses, literature review, data acquisition, and phylogenetics training.

Years 2 and 3: Simulations of birth-death models, and analysis of fossil record patterns.

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.

Training & Skills

In the course of this project, the student will become proficient in most paleobiological subfields, including phylogenetics, macroevolution, and statistics. The student will learn how to analyse and model vast amounts of data, which will serve as excellent preparation for future work in palaeobiology or related disciplines. Training will be provided on how to present scientific results, and how to write scientific papers for publication.

References & Further Reading

Benson, R. B., Campione, N. E., Carrano, M. T., Mannion, P. D., Sullivan, C., Upchurch, P., & Evans, D. C. (2014). Rates of dinosaur body mass evolution indicate 170 million years of sustained ecological innovation on the avian stem lineage. *PLoS Biology*, *12*(5), e1001853.

Felsenstein, J. (1985). Phylogenies and the comparative method. *The American Naturalist*, *125*(1), 1-15.

Harmon, L. J., & Harrison, S. (2015). Species diversity is dynamic and unbounded at local and continental scales. *The American Naturalist*, *185*(5), 584-593.

Rabosky, D. L., & Hurlbert, A. H. (2015). Species richness at continental scales is dominated by ecological limits. *The American Naturalist*, *185*(5), 572-583.

Sepkoski, J. J. (1984). A kinetic model of Phanerozoic taxonomic diversity. III. Post-Paleozoic families and mass extinctions. *Paleobiology*, *10*(2), 246-267.

Webster, A. J., Payne, R. J., & Pagel, M. (2003). Molecular phylogenies link rates of evolution and speciation. *Science*, *301*(5632), 478-478.

Further Information

Contact: Erin Saupe (erin.saupe@earth.ox.ac.uk) or Roger Benson (roger.benson@earth.ox.ac.uk)