Project Title	Angiosperm evolution and the Arctic floral revolution
Host University	The Open University
Theme	Organisms & Ecosystems Dynamic Earth
Key words	Plants, evolution, climate, diversity
Supervisory team	**PI:** Dr Luke Mander, The Open University, Luke.Mander@open.ac.uk **Co-I:** Dr Angela L. Coe, The Open University, Angela.Coe@open.ac.uk ; Robert A. Spicer, R.A.Spicer@open.ac.uk
Is the PhD suitable for part time study?	Yes

Project Highlights:

- Research the evolution of a vitally important group of organisms, flowering plants
- Contribute to understanding of the role of plants in climate change
- Training in palynology, plant palaeobiology and evolution

Overview:

Angiosperms (flowering plants) are an extremely diverse group of terrestrial plants composed of an estimated 260,000 species. They are characterised by high morphological diversity, with an array of life forms that includes herbs, epiphytes, bulbs, aquatic plants, shrubs and trees. Angiosperms also have unique anatomical features that enable them to be powerful agents of climatic change, and their evolution represents a fundamental event in the evolution of the Earth and the climate system.

Despite the evolutionary and climatic importance of angiosperms, our understanding of their long-term patterns of early evolution remains patchy. Existing data from North America indicate that angiosperms radiated during the Cretaceous period (~150–65 million years ago), but that their taxonomic and morphological evolution was decoupled (Lupia 1999). In particular, the earliest phases of angiosperm evolution were characterised by the rapid and explosive addition of novel and highly disparate morphologies as angiosperms spread over the Earth.

However, this macroevolutionary pattern has only been reported in North America at the stage level using published literature. Consequently, it is currently unclear whether the early and rapid evolution of novel and highly disparate morphologies is characteristic of angiosperm evolution in general, or a regional phenomenon. Additionally, the coarse time-scales of existing macroevolutionary analyses (Lupia 1999) mean that we do not know whether these plants speciated gradually, or their evolution was characterised by a punctuated pattern with periods of rapid speciation followed by long-term stasis (Benton and Pearson 2001).

This PhD project will address these fundamental evolutionary issues by using fossil pollen from existing rock samples taken from the Albian–Maastrichtian Alaskan Arctic Slope (Herman et al. 2016), and the early Cenomanian (~98–95 Ma) Warder Formation, New Zealand. This project has aims to: (1) Make a quantitative assessment of the taxonomic diversity and morphological disparity of angiosperm pollen from the Albian–Maastrichtian of the Alaskan Arctic Slope. (2) Reconstruct the mode of angiosperm evolution in this region. (3) Generate a palaeobiogeographic comparison of the Alaskan Arctic Slope and the Warder Formation, New Zealand.

Figure 1. Nymphaeaceae (Water lily) one of the angiosperms that evolved during the Cretaceous.

Methodology:

Existing rock samples (150 from Alaska and 40 from New Zealand) will be macerated in the laboratory using standard palynological processing techniques to release fossil angiosperm pollen grains. The diversity and disparity of these pollen grains will be assessed by scoring individual specimens for discrete morphological characters and measuring the nature of morphospace occupation through time using the methods of Mander (2016). The mode of angiosperm evolution will be assessed by making morphometric measurements of key taxa. These measurements will be plotted against time to test for gradual versus punctuated modes of evolution. Biogeographic comparison between the Cenomanian of Alaska and New Zealand will involve reconstructing the diversity and composition of the vegetation in these two regions using fossil pollen.

Training and skills:

This project will provide specific training in: (1) Palynological techniques to extract fossil pollen from rock samples. (2) The description of plant morphology using morphometric techniques. (3) The use of high-resolution optical and electron microscopy. (4) Macroevolutionary analytical techniques to examine the morphological and taxonomic diversification of major clades.

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and 'free choice' external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

Partners and collaboration (including CASE):

This project will benefit from collaboration with Dr. Liz Kennedy (GNS Science, New Zealand)

Possible timeline:

Year 1: Macerate rock samples in laboratory in order to release fossil angiosperm pollen grains. Generate a morphospace for early angiosperm pollen. Attend the Palaeontological Association Annual Meeting.

Year 2: Complete a morphospace analyses of Alaskan and New Zealand angiosperm pollen. Make morphometric measurements of key angiosperm pollen grains to reconstruct the mode of flowering plant evolution. Compare results from the two sites. Preparation of manuscript. Present at the Palaeontological Association Annual Meeting. Complete work placement.

Year 3: Complete interpretation. Prepare two further manuscripts and write up thesis. Present results at the Geological Society of America annual meeting.

Further reading:

Benton, M. J. and Pearson, P. N. (2001) 'Speciation in the fossil record', *Trends in Ecology & Evolution*, 16, 405-411.

Herman, A. B., Spicer, R. A. & Spicer, T. E. V. (2016) 'Environmental constraints on terrestrial vertebrate behaviour and reproduction in the high Arctic of the Late Cretaceous', *PPP*, 295, 423-442.

Lupia, R. (1999) 'Discordant morphological disparity and taxonomic diversity during the Cretaceous angiosperm radiation: North American pollen record', *Paleobiology*, 25, 1-28.

Mander, L. (2016) 'A combinatorial approach to angiosperm pollen morphology', *Proceedings of the Royal Society B*, 283, 20162033.

Further details:

Students should have a strong background in geology, biology or both, and a keen interest in undertaking micropalaeontological work. Some prior research experience in palaeobiology would be useful. Please contact **Luke Mander (luke.mander@open.ac.uk)** for further information.

Applications must include:

- a cover letter outlining why the project is of interest and how your skills are well suited to the project
- an academic CV containing contact details of three academic references
- a CENTA application form, downloadable from: http://www.centa.org.uk/media/1202/centa-studentship-application-form.docx
- and an Open University application form, downloadable from: https://tinyurl.com/y73hrfou

Applications should be sent to **STEM-EEES-PhD-Student-Recruitment@open.ac.uk** **by 12pm (noon) on 21st January 2019**