**Research Experience Placement (REP) Scheme 2024**

**Supervisor Project Proforma**

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| **Project title:** | The branching architecture of early leaf venation networks |
| **Host Institution:** | The Open University |
| **Project supervisor (name, department):** | Luke Mander (Environment, Earth and Ecosystem Sciences) |
| **Project enquiries (supervisor email):** | Luke.Mander@open.ac.uk |
| **Co-Supervisor, if any (name, department):** | Tom Stubbs (Life, Health and Chemical Sciences) |
| **Proposed start date:** | 1/7/24 |
| **Project description**  Leaf venation is a biological distribution network that is morphologically diverse. Some networks are characterised by a simple dichotomously branching tree-like topology in which veins bifurcate, while others are characterised by a complex reticulate topology in which veins branch and reconnect to form loops. The first evolutionary transition from branched to loopy network architectures took place in the Carboniferous and is recorded by the leaf fossil *Reticulopteris muensteri* and reticulate leaf venation subsequently evolved multiple times independently among unrelated seed plants during the latest Palaeozoic and Mesozoic. Reticulate venation is thought to be a key anatomical innovation that provides several advantages over branched venation, including increasing the vein length per area of the leaf, resistance to damage, as well as enhancing physiological parameters related to photosynthesis. Studies of modern leaves have suggested that in both dichotomous and reticulate venation networks, the diameter of individual vein segments may follow scaling laws, in which sums of the diameters of two converging conduits equal the diameter of the next higher order conduit (da Vinci's model), or the sum of the squares of the diameters of two converging conduits equals the square of the diameter of the next higher order conduit (Murray's model) (Carvalho et al. 2017). However, at present, it is unclear whether or not the first leaf venation networks follow either da Vinci's or Murrays model, which prevents understanding of whether the scaling of branching architecture in leaf venation networks is a primitive or derived condition. The overall goal of this project, therefore, is to quantify the branching architecture of early leaf venation networks during the Carboniferous.  This project will quantify the branching architecture of early leaf venation networks by making measurements of individual vein segments in published palaeobotanical papers and monographs. The following eight taxa with botanical affinity age and venation type (references in brackets) will be investigated:  *Linopteris subbrongniartii*, Pteridosperm (Medullosales), Pennsylvanian, Reticulate (Laveine 1967: Laveine, J.-P. 1967. Les Neuroptéridés du Nord de la France. Études Géologiques pour L'atlas de Topographie Souterrain. I. Flore Fossile, Fascicule 5. Service Géologique des H.B.N.P.C., Lille.)  *Lonchopteris* bricei, Pteridosperm (Medullosales), Pennsylvanian, Reticulate (Crookall 1955–1976: Crookall, R. 1955–1976. Fossil plants of the Carboniferous rocks of Great Britain. *Memoirs of the Geological Survey of Great Britain, Palaeontology*, 4, 1–1004*.*)  *Lonchopteridium laxereticulosum*, Pteridosperm (?Medullosales), Pennsylvanian, Reticulate (Boureau and Doubinger 1975: Boureau, E. and J. Doubinger. 1975. Pteridophylla (Première Partie). Traité de Paleobotanique, Tome IV, Fascicule 2. Vol 2, Masson, Paris.)  *Reticulopteris muensteri* small morphotype, Pteridosperm (Medullosales), Pennsylvanian, Reticulate (Zodrow and Cleal 1993: Zodrow, E.L. and Cleal, C.J. 1993. The epidermal structure of the Carboniferous gymnosperm frond *Reticulopteris*. *Palaeontology*, 36, 65–79.)  *Reticulopteris muensteri*, Pteridosperm (Medullosales), Pennsylvanian, Reticulate (Zodrow and Cleal 1993)  *Neuropteris jongmansi*, Pteridosperm (Medullosales), Pennsylvanian, Branched (Cleal and Thomas 1994: Cleal, C.J. and Thomas, B.A. 1994. Plant Fossils of the British Coal Measures. *Palaeontological Association Field Guides to Fossils*, 6, 1–222.)  *Neuropteris heterophylla*, Pteridosperm (Medullosales), Pennsylvanian, Branched, (Cleal and Thomas 1994)  *Rhacopteris lindsaeformis*, Pteridosperm (?Lyginopteridales), Mississippian, Branched (Galtier 2010: Galtier, J. 2010. The Origins and Early Evolution of the Megaphyllous Leaf. *International Journal of Plant Sciences*, 171, 641–661.)  Published images of leaves will be photographed, loaded into ImageJ and calibrated for size. For branched venation, vein segments will be ranked according to the Strahler branching system in which the most distal veins on each leaf blade are ranked 1, and increasing ranks are assigned to veins formed by the junction of two equally ranked veins (Carvalho et al. 2017). For reticulate venation, the spaces between veins (areoles) will be numbered from the leaf base to the leaf tip, and veins will be ranked according to the areole they border. For both venation classes, the diameter of vein segments at each rank will be measured using ImageJ. The scaling relationship between vein diameter and vein rank will be inspected graphically using log-log plots. | |
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| **Project timeline:** | |
| **Week 1:** Orientation  **Week 2:** Gathering images from published literature  **Week 3:** Dividing venation networks into ranks  **Week 4:** Measuring venation segments  **Week 5:** Plotting results and data exploration  **Week 6:** Project write-up | |
| **Candidate requirements:** | |
| Interest in palaeontology, evolution and plants. | |
| **Background reading and references:** | |
| Carvalho, M.R., Turgeon, R., Owens, T. and Niklas K.J. 2017. The scaling of the hydraulic architecture in poplar leaves *New Phytologist*, 214, 145–157.  Carvalho, M.R., Turgeon, R., Owens, T. and Niklas K.J. 2017. The hydraulic architecture of *Ginkgo* leaves. *American Journal of Botany*, 104, 1285–1298.  Hetherington, A.J., Berry, C.M. and Dolan, L. 2016. Networks of highly branched stigmarian rootlets developed on the first giant trees. *Proceedings of the National Academy of Sciences, USA,* 113, 6695–6700.  Mander, L., and Williams, H.T.P. (2024) The robustness of some Carboniferous fossil leaf venation networks to simulated damage. *Royal Society Open Science*, 11, 240086. | |

**To be completed by institutional CENTA PoC**

I confirm that:

* The host institution takes responsibility for selecting a suitable undergraduate student and ensuring eligibility (see NERC REP student eligibility requirements above) and confirming their eligibility using the UKRI criteria listed under the NERC REP student eligibility criteria
* This REP project falls within the NERC remit and is of suitable quality
* Appropriate supervisory arrangements are in place
* The student recruited to undertake this placement will have a PhD student mentor from the DTP/CDT
* The application processes used will be inclusive and accessible
* Reasonable adjustments will be made for students that need them whilst undertaking placements
* The placement will be carried out in accordance with all applicable ethical, legal and regulatory requirements including but not limited to relevant provisions of the General Data Protection Regulation, the Data Protection Act 2018, the Bribery Act 2010, the Fraud Act 2006, the Equality Act 2010 and the Modern Slavery Act 2015
* The host organisation takes responsibility for identification, protection and exploitation of any intellectual property rights arising from the work
* All facilities, agreements about access and collaborations necessary for the work will be obtained before the work commences and can be ensured through the period of the work
* All costs awarded by NERC for the REPs will be used and accounted for appropriately
* A report of the project by the student will be submitted no later than one week after the end date of the placement or Friday 27th September 2024, whichever falls first.

Signed: Luke Mander

Date: 2/5/24

Position: Senior Lecturer in Earth Sciences