Project Title | Bio-precipitation or self-cryopreservation: Why does pollen nucleate ice?
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Host University | University of Warwick
Themes | Climate & Environmental Sustainability, Organisms & Ecosystems
Supervisory team | PI: Dr Thomas Whale, Leverhulme Early Career Fellow, Department of Chemistry, University of Warwick. 
Co-I: Prof Matthew Gibson, Professor, Warwick Medical School and Department of Chemistry, University of Warwick, 
Dr Daniel Ballesteros Bargues, Early Career Research Fellow, Royal Botanic Gardens Kew

Project Highlights:
- Work with Royal Botanic Gardens Kew to understand how the biosphere influences weather and climate
- Discover how the evolutionary history of plants interacts with our atmosphere
- Develop a diverse and up-to-date skill set by working with chemists, plant scientists and atmospheric scientists

Overview:
Nucleation of crystalline ice from supercooled water plays a critical role in the glaciation of mixed-phase clouds and thereby impacts both weather and climate (Murray et al., 2012, Vergara-Temprado et al., 2018). Ice-active polysaccharides (IAPs) associated with pollen grains of some plant species are known to nucleate ice effectively and are present in the atmosphere in potentially significant quantities (Dreischmeier et al., 2017, Pummer et al., 2012, O’Sullivan et al., 2015, Diehl et al., 2002, von Blohn et al., 2005).

Ice nucleation caused by birch pollen IAPs is remarkably specific in nature, occurring sharply at around -16°C (Fig. 1(a)), indicating that IAPs have evolved to interact with ice. It is not known why birch pollen produces IAPs or how well the vast majority of pollens nucleate ice as less than 10 species have been studied (von Blohn et al., 2005). There are two obvious reasons for pollens to evolve IAPs.

1) To control precipitation and aid return to the ground having been lofted to altitude by wind. This is an example of ‘bio-precipitation’ where life interacts with clouds to propagate itself.
2) To improve tolerance of cold temperatures by controlling ice formation, be it in clouds or at ground level. Different species pollens are known to be desiccation tolerant to varying extents, depending on the specific dispersal methods they employ. This may be related to their ability to nucleate ice.
Fig 1 (a) ice nucleation temperatures for birch pollen grains, and for washing water with pollen grains removed by filtration and centrifugation (O’Sullivan et al., 2015) (b) SEM micrograph of a pollen grain. (c) Sculptures of pollen grains at the Millennium Seed Bank, Wakehurst Gardens on a snowy day.

The student will collect pollen from plant species held in the collections at Royal Botanic Gardens (RGB) Kew and measure their ice nucleation ability and freeze tolerance to generate a comprehensive multi-species dataset. Armed with this dataset the student will conduct an analysis of the phylogenetic background and ecological role of pollen ice nucleation, allowing an assessment of why pollen nucleates ice. This information will be of ecological interest and improve understanding of biosphere/atmosphere interaction.

Methodology: Pollen grains from a wide range of plant species will be obtained from the RGB Kew collections and their ice nucleation ability assessed using droplet freezing techniques (Whale et al., 2015). The polysaccharides responsible for ice nucleation will be isolated by ice chromatography and characterized. A test for the presence of pollen IAPs and a method for selectively denaturing them will then be developed. The relationship between ice nucleation and pollen desiccation tolerance will be obtained from the literature and empirical determination (Nebot et al., 2018). Pollen grains will be frozen in liquid water after Williams (2013), and post-thaw viability assessed. Pollen viability tests will be optimized at the species level. This will show whether the IAPs help pollen grains to survive freezing. Results will be compared with existing phylogenetic and ecological datasets to assess which plant families nucleate ice and to trace back the genetic origin of plant ice nucleation (e.g. Colville and Pritchard, 2019).

Training and skills: At the University of Warwick (UoW) students will receive training in ice specific analytical techniques and biomacromolecule characterisation as well as general chemical analytical techniques such as Raman and IR spectroscopy, differential scanning calorimetry and X-ray diffraction, amongst others.

RBG Kew will provide extensive relevant training in plant science. RBG Kew also has particular expertise in science communication with specific training provided and opportunities to write for the RGB Kew website and social media channels and engage with media outlets.

Skills developed in the course of the PhD will be interdisciplinary and relevant to a wide range of fields in industry and academia including atmospheric science, plant science, analytical chemistry and science communication.

Partners and collaboration: This project will be a partnership between the Chemistry department at UoW and RBG Kew. The student will be flexibly based between the two institutions, making best use
of the outstanding facilities and resources at both. At UoW, Dr Whale provides expertise ice science and ice nucleation measurement and Prof Gibson provides expertise on biomacromolecular science. Dr Ballasteros and RGB Kew provide expertise on plant science, ecology and pollen cryopreservation. The project can also make use of the presence of Dr Gabriele Sosso at UoW for complementary molecular dynamics simulations of ice formation in biological systems.

Possible timeline: Year 1 - Q1 and Q2: The student will conduct ice nucleation and ice chromatography experiments on known pollen ice nucleators at the UoW, aiming to isolate and characterise IAPs

Q3 and Q4: After developing skills in ice nucleation measurement the student will work at RBG Kew (both Kew and Wakehurst sites) obtaining pollen samples from the collections and testing their ice nucleation ability.

Year 2 - Q1 and Q2: Parallel to work on developing a database on pollen ice nucleation work aimed at isolating IAPs will be applied to the newly sourced pollens from RGB Kew.

Q3 and Q4: The student will assess the impact of freezing in water on pollen viability, as well as the desiccation tolerance/sensitivity of the studied pollen.

Year 3 - Using data on pollen ice nucleation ability and freeze tolerance obtained in the course of the first two years, together with literature data on the phylogenetic and ecological profiles of the relevant plant species, the student will establish why pollen nucleates ice. Experimental work will be conducted as necessary to fill in gaps and test hypotheses.

Further reading:


**Further details:**
Enquiries are very welcome. Please contact Dr Whale at tom.whale@warwick.ac.uk or Dr Ballasteros D.Ballesteros@kew.org. Further information about RGB Kew is available at (https://www.kew.org/) and further information about the Chemistry department at the University of Warwick is available at (https://warwick.ac.uk/fac/sci/chemistry/).