PhD Project Advertisement

Project title: A receptor-ligand module with practical applications to improve food production
Project No: FBS2024-014-Stephens-ra

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Andrew Quigley, Diamond Light Source and Research Complex at Harwell

Project description:

Background:
Most of our food is a product of plant reproduction with fertility and seed set critical for crop yield and thus food security. The genetically controlled process of self-incompatibility (SI) is used by ~50% of flowering plants to prevent self-fertilization and thus promote outbreeding and fitness of plant species. For this reason, SI has made a significant contribution to the evolutionary success of flowering plants. Mechanistic understanding of SI can lead to improvements of plant breeding practises to produce better crop. After pollination, SI utilizes cell-cell recognition to prevent self-fertilization by inhibition of pollen tube growth, which is crucial for the delivery of sperm cells to the egg cell inside the pistil. This involves a highly specific interaction between a pollen-expressed protein and a cognate pistil protein that results in recognition and inhibition of genetically identical or self- (incompatible) pollen, but not cross (compatible) pollen. The SI system of Papaver, which triggers programmed cell death (PCD) in incompatible pollen tubes, is one of the best-studied SI systems. Papaver SI is controlled by a bipartite module comprising two polymorphic S-determinants: A pollen-expressed transmembrane protein, PrpS, interacts with cognate PrsS, a small protein secreted by the stigma, to induce rapid pollen tube growth arrest followed by PCD. It was established that the Papaver SI-PCD system can be functionally transferred to Arabidopsis, despite the huge evolutionary distance (~140 million years apart), effectively rendering Arabidopsis self-incompatible (Lin et al., 2015).

This demonstrates that PrsS and PrpS can act as a synthetic S-locus that can be functionally transferred between highly diverged plant species. Thus, it may be now possible to introduce SI into crops. If this is possible, the Papaver system may facilitate the ability to breed hybrid crops – plants whose 'hybrid vigour' gives them better yield and strength than their parents.

Although we have detailed knowledge of the downstream signalling events triggered by the PrpS-PrsS receptor-ligand interaction (Goring et al., 2023), we have very little understanding of the biological function of the PrpS-PrsS module. For the Papaver SI system to fully reach its translational potential that can lead to innovative applications in agriculture, it is essential to resolve this knowledge gap. This will be the focus of the project.

Aim and Objectives:
Although we have a lot of information about the signalling events downstream of a cognate receptor ligand interaction, little is known about the PrpS receptor itself. The aim of this exciting multidisciplinary project is to identify the functional nature of the PrpS receptor and establish the dynamics of PrpS-PrsS receptor ligand interactions.

Objective 1: Supervised by Dr Andrew Quigley at Diamong Light Source, the student will have access to state-of-the-art facilities to obtain structural information of the PrpS receptor. Size Exclusion Chromatography with Multi-Angle Light Scattering (SEC-MALS) will be used to determine if PrpS forms stable complexes while flow-induced dispersion analysis (FIDA) will determine how these are affected by the ligand. PrpS proteins will be purified from membrane preparations and high-resolution structural information, in presence and absence of ligand, will be obtaining through X-ray crystallography and cryogenic electron microscopy (cryo-EM).

Objective 2. Although there is evidence that Ca2+ influx triggers SI, how this is achieved is a complete mystery. We hypothesize that PrpS functions as an ion channel, allowing Ca2+ influx. Supervised by Prof Gary Stephens (Reading), the student will use electrophysiological studies of PrpS expressed in a heterologous cell system such as HEK cells using available biochemistry and molecular biology techniques to establish if PrpS acts as a channel. Using patch-clamp electrophysiology the student will identify PrsS-induced biophysical (channel activation and kinetics, channel conductance and ion selectivity) and pharmacological properties.

Impact:
Although fundamental by nature, the outcomes of this collaborative project will underpin the ability to breed hybrid crops – plants whose 'hybrid vigour' gives them better yield and strength than their parents. In addition, PCD constitutes a source of unexplored molecular targets for new herbicidal modes of action. Functional knowledge about SI-PCD can therefore lead to the development of smart herbicides.

Training opportunities:

Besides being supervised by an inter-disciplinary supervisory team, the student will benefit from being integrated in the Pharmacology Group, School of Pharmacy, in the heart of the University of Readings' Whiteknights campus, which is an ideal environment for this research with numerous links between Pharmacology, Food Science (both departments are part of the School of Chemisty, Food and Pharmacy) and several existing research links with nearby Diamond Light Source facility.

The student will be trained in a number of areas relevant to fundamental biosciences. Supervised by Gary Stephens (Reading), the student will receive training in patch-clamp electrophysiology and pharmacological approaches to obtain functional information about the PrpS-PrsS receptor-ligand module. Supervised by Andrew Quigley the student will receive training in cutting-edge techniques available at Diamond Light Source and the Research Complex at Harwell to obtain structural information about the module and its individual components. The student will spend some time with Maurice Bosch at IBERS, Aberystwyth, to obtain practical training of the Papaver SI system and high-resolution live cell imaging techniques (Wang et al., 2022).

Student profile:

This project would be suitable for students with a degree in biology, chemistry, pharmacy, pharmacology, food science or a closely related subject. We are looking for a student that shows a keen interest in pursuing this multidisciplinary PhD project that will provide the candidate with training and skills in a range of varied techniques.

Stipend (Salary):

FoodBioSystems DTP students receive an annual tax free stipend (salary) that is paid in instalments throughout the year. For 2023/24 this is £18,622 and it will increase slightly each year at rate set by UKRI.

Equality Diversity and Inclusion:

The FoodBioSystems DTP is committed to equality, diversity and inclusion (EDI), to building a doctoral researcher(DR) and staff body that reflects the diversity of society, and to encourage applications from under-represented and disadvantaged groups. Our actions to promote diversity and inclusion are detailed on the FoodBioSystems DTP website.

In accordance with UKRI guidelines, our studentships are offered on a part time basis in addition to full time registration. The minimum registration is 50% FT and the studentship end date will be extended to reflect the part-time registration.

References:

Goring et al. (2023) Current Biology 33: R530-R542.
Lin et al. (2015) Science 350: 684-687.
Wang et al. (2022) New Phytologist 236: 1691-1707.

For up to date information on funding eligibility, studentship rates and part time registration, please visit the FoodBioSystems website.