Project title: AI-guided genetic and cellular immunity for pesticide-free crop protection

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Project Description:

Synthetic fungicides are applied intensively to solanaceous crops such as potato, tomato, pepper and aubergine to control oomycete diseases, with major consequences for biodiversity, water quality and greenhouse gas emissions from manufacture and application. This project directly addresses the Grantham theme **"Pesticides (Alternatives & Phase-Out)"** by developing **next-generation biological crop protection** based on AI-guided discovery and engineering of immune receptors that sense oomycete pathogens, offering genetic and peptide-based alternatives to fungicides.

Oomycete pathogens such as *Phytophthora infestans* deploy a rich repertoire of pathogen-associated molecular patterns (PAMPs) and effector proteins that can be recognised by plant immune receptors. However, many relevant receptors remain unknown, and existing receptors are often narrowly tuned or vulnerable to pathogen "escape" mutations. This 4-year PhD aims to: (i) systematically identify oomycete-derived PAMPs/proteins/effectors and their corresponding plant immune receptors, (ii) engineer these receptors for improved activity and sensitivity, including robust detection of escape variants, and (iii) design synthetic immune agonists that activate known receptors without genetic modification.

Using *Nicotiana benthamiana* as a versatile solanaceous model alongside selected crop species (potato, tomato, pepper, aubergine), the student will:

1. **Discover recognition pairs:** Screen candidate PAMPs, virulence factors and effectors from major oomycete pathogens for their ability to trigger immune responses, and use genetic, biochemical and AI-assisted receptor–ligand prediction tools to identify the corresponding pattern-recognition receptors and NLRs.
2. **Engineer resilient receptors:** Apply AI-based protein structure and interaction modelling to redesign receptor domains for stronger binding, enhanced signalling output and the ability to recognise pathogen escape variants, followed by functional testing in planta under oomycete challenge.
3. **Design synthetic immune agonists:** Use AI-guided peptide design to generate synthetic peptides that optimally engage known immune receptors, providing a complementary, sprayable or deliverable **biological alternative to fungicides** that can boost immunity without genetic modification of the crop.

Immune traits and synthetic peptides will be benchmarked against standard fungicide regimes to estimate their **pesticide-replacement potential** and to explore deployment scenarios compatible with **regenerative, low-input production systems** where chemical use is minimised.

The student will gain expertise in AI-guided structural biology, plant-pathogen interactions, protein engineering, and crop disease resistance. The project leverages established Imperial facilities,

collaborations with industry partners including Resurrect Bio, and builds on our recent discovery that NLR receptors can function at organellar membranes beyond traditional plasma membrane localization.

To apply:
Please email o.bozkurt@imperial.ac.uk with the following documentation:
- Statement of Purpose
- Your CV
- At least two references must be emailed to *Tolga Bozkurt* (by the referees)