Project title: Harnessing Phage Satellites for Next-generation Biological Crop Protection

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Project Description:
Antibiotic resistance and the overuse of chemical pesticides threaten both human health and environmental sustainability. There is an urgent need to develop precision biological tools that can target bacterial pathogens without disrupting beneficial plant microbiomes or ecosystems. Our recent research uncovered a novel mechanism by which phage-inducible chromosomal islands (PICIs), specifically capsid-forming PICIs (cf-PICIs), hijack phage tails from unrelated bacteria to assemble chimeric particles[1,2]. This process enables cf-PICIs to deliver their DNA across bacterial species or with high strain-level precision[2,3]. Such flexibility offers a powerful platform to overcome the long-standing host-range barrier in phage biology.
This PhD project aims to decode and engineer cf-PICI–phage interactions to develop a new generation of precision biological control agents for sustainable crop protection.

The objectives are to:

1. Determine the molecular mechanisms that enable cf-PICIs to interact with and hijack phage tails from diverse bacterial species.
2. Engineer cf-PICIs to deliver custom DNA payloads - such as inhibitory RNAs, antimicrobial peptides, or CRISPR-based systems - specifically into major crop pathogens (*Pseudomonas syringae*, *Xanthomonas* spp.), while sparing beneficial microbiota.
3. Explore the use of cf-PICIs as diagnostic tools, by encoding marker genes (e.g., fluorescent or enzymatic reporters) to detect and monitor bacterial strains within plant microbiomes.

Methodology:
The PhD student will combine comparative genomics, cryo-electron microscopy, and molecular genetics to map cf-PICI–phage interactions and identify tail-binding determinants. Synthetic biology approaches will then be applied to reprogramme cf-PICIs as modular DNA delivery vehicles for targeted delivery of inhibitory RNAs, peptides, or CRISPR-based payloads into crop pathogens.

Expected impact:
By exploiting naturally evolved mechanisms of horizontal gene transfer, this research will pioneer an innovative framework for biological pest management that reduces pesticide reliance and promotes resilient agricultural ecosystems. The project aligns closely with the Grantham Institute's priorities in "Next-gen biological crop protection," combining environmental microbiology, molecular evolution, and synthetic biology to deliver climate-smart, low-impact alternatives for sustainable food production.

References:

1. Penadés JR, Seed KD, Chen J, Bikard D, Rocha EPC. Genetics, ecology and evolution of phage satellites. Nat Rev Microbiol. 2025 Jul;23(7):410-422. doi: 10.1038/s41579-025-01156-z. Epub 2025 Mar 27. PMID: 40148600.
2. He L, Patkowski JB, Wang J, Miguel-Romero L, Aylett CHS, Fillol-Salom A, Costa TRD, Penadés JR. Chimeric infective particles expand species boundaries in phage-inducible chromosomal island mobilization. Cell. 2025 Sep 3:S0092-8674(25)00974-2. doi: 10.1016/j.cell.2025.08.019.
3. Penadés JR, Gottweis J, He L, Patkowski JB, Daryin A, Weng WH, Tu T, Palepu A, Myaskovsky A, Pawlosky A, Natarajan V, Karthikesalingam A, Costa TRD. AI mirrors experimental science to uncover a mechanism of gene transfer crucial to bacterial evolution. Cell. 2025 Sep 9:S0092-8674(25)00973-0. doi: 10.1016/j.cell.2025.08.018.

To apply:

Please email t.costa@imperial.ac.uk with the following documentation:

- Statement of Purpose
- Your CV
- At least two references must be emailed to *Tiago R D Costa* (by the referees)