

The true value of symbiosis: The role of Earthworm Microbiome in host plasticity and soil health

Supervisors:

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Hosting institution: Cardiff University

Project description: Background: Earthworms are the single largest contributors to the soil invertebrate biomass in many ecosystems and have long been recognized for the benefits they bring to the environment. Important functions of earthworms include processes such as soil aeration, bioturbation and organic matter fragmentation that are vital for promoting soil structural development and nutrient cycling. The earthworm plays host to a number of discrete bacterial communities acquired either horizontally from the surrounding soil, as with the gut fauna [1], or through vertical parental transmission in the cocoon, as observed for the nephridial symbiotes. The earthworm gut microfauna exists within a discrete environment with significant changes in pH, moisture, oxygen and nutrient availability to the soil, and plays host to community profiles distinct from the soil in which they reside [2]. As soil organisms, earthworms are in intimate contact with changing soil chemistries and bio-available pollutants where environmental stressors (such as metals) radically change the bacterial community profile and can eradicate known earthworm symbiotes [2].

Objectives: By characterizing and manipulating the vertical and horizontally transmitted earthworm associated microbial communities we aim to determine the contribution they play in the ability of the host to function, adapt and proliferate in an extreme range of soil environments, both natural and anthropogenic. This will be achieved by converting the following objectives:

- i) To derive the functional capacity of the host-associated microbiome in relation to earthworm phenotype.
- ii) To determine the fitness of earthworms accommodating microbiomes transplanted from hosts resident on contrasting soil environments (heavy metals and pH).
- iii) To establish the vertically transmitted microbiome and the degree to which it can be manipulated via community transplantation to sterile cocoons.
- iv) To determine whether mobile genetic elements within the earthworm microbiome facilitate viability within host resident to extreme soil environments.

Approach: We will exploit next-generation sequencing (NGS) to evaluate the expression patterns of the earthworm microbiome ultimately determining its contribution to host health, plasticity and functionality. Functional microbiome analysis will be performed through meta-transcriptome analysis to compliment 16S rRNA based microbial diversity analysis. Transplantation of micro-communities into sterile hosts, both adult and embryonic) will allow the independent manipulation of vertical and horizontal microbial communities. Both informatics and experimental approaches will investigate the role played by mobile genetic elements in the adaptation of the earthworm symbiotic bacterial populations to soil chemistry and the consequential plasticity of the host (Obj. iv).

[1] Drake, H.L., and Horn, M.A. (2007) As the worm turns: The earthworm gut as a transient habitat for soil microbial biomes. *Annual Review of Microbiology* 61: 169-189.

[2] Pass, D., Morgan, A.J., Field, D., Weightman, A. J. and Kille, P. (2013) The earthworm microbiome and the effect of extreme anthropogenic contamination on host-associated microbiota. In Preparation.

Training opportunities: The Supervisory Team: Primary supervision at each institution will be provided by Prof. Peter Kille (PK – Cardiff University) and Dr David Spurgeon (DS – CEH Wallingford) with secondary supervision being provide by Prof. Andrew Weightman (AW – Cardiff University). Between them PK and AW have graduated 50 PhD students, with 5 of PK students being partnerships with Dr David Spurgeon a track record that attests to their experience at postgraduate training and their ability to balance the demands of providing an appropriate training environment for a studentship in a interdisciplinary and multi-institutional project. AJW is a molecular microbiologist and has successfully supervised 24 PhD students; he has directed bioinformatic projects leading to the development of tools for the analysis of 16S rRNA (e.g. Pintail programme now used by the RDP) and metagenomic gene sequences. This extended advisory team each bring complementary skills ranging from bioinformatics and earthworm genomics through microbial ecology to soil ecology and population modelling.

Training Environment: Day-to-day supervision will be provided by PK with the student being expect to comply with the official graduate training program of the School of Biosciences which will aid his personnel development, monitor his progress and ensure the quality of his research output and supervision. Monthly, meetings of the full supervisory team (either in person or via video conference) will provide a forum at which the student can benefit from the wealth of experience and interest of the extended advisory group. The student will be integrated into the both the Kille/Weightman research teams at Cardiff University (currently this represents 9 PhD students and approximately an equal number of postdoctoral scientists working in adjacent laboratory) together with the Spurgeon/Svendson team at CEH. The studentship will be associated with the Division of Organisms and the Environment (OnE) working within the Genomes Diversity and Adaptation area lead by Prof. Peter Kille (<http://www.cf.ac.uk/biosi/research/organismsandenvironment/index.html>). The student will have access to the computation and support facilities at both Cardiff University and CEH including the super-computing facility based at Advanced Research Computing @ Cardiff (ACCRA - <http://www.cardiff.ac.uk/arcca/>). The project will exploit the mesocums, constant environment facility, Ion Torrent Next Generation Sequencing Platform and Vermi-culture unit hosted at CEH-Wallingford.

Skill based training. Expert training in statistical methodology and bioinformatics will be delivered through hands on course already in place at the Cardiff School of Biosciences together with specialist course on microbial diversity informatics delivered through ELIXIR-UK for which PK is the NERC representative. Earthworm husbandry and demographic analysis of earthworm population viability will be delivered by DS whilst microbial ecology and community analysis will benefit from AW experience and expertise.

Generic training. The study will have access to all training provided by the primary host, Cardiff School of Bioscience, but will also be able to exploit the wide range of CEH run training activities. Cardiff activities provided by CEH that are linked to the GW4+ DTP and also the University. DTP specific course will also be available through the approved DTP training program.