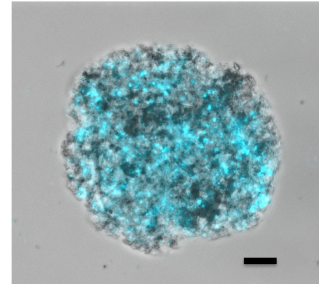


# Understanding Microbial Ecosystems

Mini project proposal by Orkun S Soyer (PI) and Stefan Grosskinsky (Co-I)

## **Project Outline:**

Microbes are capable of diverse biochemical conversions and readily co-exist in nature. The functional capacity of these natural communities as seen in animal guts, soil, and the ocean maintain life on Earth. This natural capacity, if understood through experiment and modeling can then lead to rational engineering of multi-species microbial systems. Such systems can deliver a step-change in biotechnology and biomedicine, leading to novel applications such as artificial guts designed to support animal farming, synthetic soils tailored to support plant growth in precision agriculture, novel biochemical conversion systems for generation of high-value compounds from defined waste streams, and artificial ecosystems for provision of life-support functions in space missions.



**Figure 1.** Fluorescent microscopy image of co-culture of a methanogen (blue fluorescent) and a sulfate reducing bacteria.

Despite this potential, understanding and engineering of functional, multi-species systems remains unachieved.

Particular roadblocks to progress are experimental methods of establishing, controlling and measuring multi-species microbial systems and their appropriate modeling through mathematical and computational approaches. The key modeling challenges include integration of ecological and evolutionary dynamics (which happen at similar timescales for microbes) and accounting for spatial dynamics (see Figure 1). In this project, you will pave the road towards addressing these challenges by developing mathematical approaches to modeling multi-species, microbial ecosystems. These efforts will be based on our on-going experimental work, in which we have established several 2- and 3-species ecosystems. One of these systems, an interaction that leads to production of methane, displays significant spatial organisation. The other system, which is being designed with the goal of achieving a “closed, self-sustaining ecosystem” features three different species with interactions spanning different time scales.

As a starting point you will develop non-spatial and spatial differential equation models of these systems and analyze ensuing system dynamics. We would like to explore the presence of multiple steady states and interesting nonlinear temporal dynamics in these systems. This approach can then be expanded to model a range of different ecosystems, consisting of different interaction patterns, as well as developing treatable predictions in our existing systems.

**References:** 1. Großkopf, Tobias, and Orkun S Soyer. "Synthetic Microbial Communities." *Current opinion in microbiology* 18C (2014). 2. Mee, Michael T, and Harris H Wang. "Engineering Ecosystems and Synthetic Ecologies." *Molecular bioSystems* 8, no. 10 (2012). 3. Reichenbach, Tobias, Mauro Mobilia, and Erwin Frey. "Mobility Promotes and Jeopardizes Biodiversity in Rock-paper-scissors Games." *Nature* 448, no. 7157 (2007).

**OSS Lab (<http://osslab.lifesci.warwick.ac.uk>):** We are based in the School of Life Sciences and are part of the Warwick Centre for Integrative Synthetic Biology (WISB, <http://wisb.warwick.ac.uk>). Members of the group have diverse backgrounds including microbial biology, engineering, mathematics and computer science and employ both experimental and theoretical approaches.

**Required Skills (Selection Criteria):** This project is best suited to candidates with a strong background in dynamical systems theory and partial differential equations. Familiarity with stochastic approaches, as well as different computing languages/platforms would be beneficial.