

Evolution in Space

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Introduction:

If we are to understand human impacts on biodiversity, we need to understand impacts on the evolutionary processes that produce that diversity. Those evolutionary processes are best understood in microbes, which are not only the major constituents of, and functional contributors to, the biosphere, but can, in many cases, be taken into the laboratory and evolved experimentally [1]. However, the gulf is large between evolution in a well-mixed culture of *E. coli* in the laboratory (e.g. [2]) and that in the diverse microbe communities of soil or ocean sediments. Perhaps the most fundamental differences between these environments are (a) the degree of spatial structuring and (b) the potential for interaction with unrelated organisms. The aim of this project is to take a combined experimental and modelling approach to help understand both these factors, and to gain a new understanding of microbial evolution in spatially structured environments, when competing with organisms of different relatedness. This will move the experimental understanding of microbial evolution a step closer to the evolutionary processes going on in natural environments.

Project Summary:

Recently, others have developed approaches to looking at the evolutionary dynamics of mutation, drift and selection in spatially structured environments in the laboratory [3]. This involves analyzing the competition of marked organisms within a single microbial colony (Fig. 1). However, there is a great deal that we do not yet understand about how evolution occurs in such contexts. For instance, how do environmentally dependent mutation rates – that we have recently characterized as occurring across widely different microbes [4] – affect evolutionary dynamics in such contexts? Importantly, almost all of the information we currently have comes from ‘domesticated’ laboratory organisms, how do such dynamics play out in more or less closely related organisms? Fortunately, culture collections are becoming available of well-characterized and differently related organisms from diverse environments (e.g. <https://evocellnet.github.io/ecoref/about/>). This project will put together the environmental organisms in spatially structured environments, and use experimental evolution to address questions about the fundamental evolutionary processes that shape the biosphere.

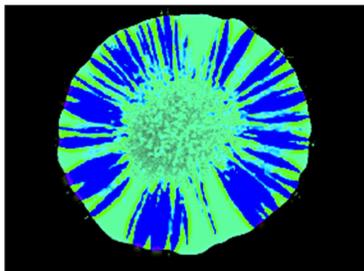
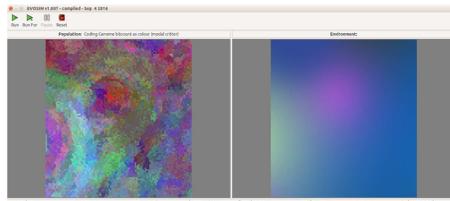


Fig. 1 Quantifying microbial competition in a spatially structured environment. Two microbes, distinguished by colour, growing together on an agar plate. The green strain starts in a minority but is fitter in this environment than the blue strain. This is apparent from the larger amount of green at the periphery than at the base of the blue streaks, by the curvature of the sector edges and from the bulges around the periphery at the green sectors. Competitive fitness may be quantified by measuring these features. (photo: Daniel Smith, Knight lab)

Making sense of what we see in the laboratory requires not only well structured experiments, but the ability to construct hypotheses for the outcomes of evolution. This is challenging in complex, spatially structured systems such as those addressed here. However, that process may be aided by computer simulation models of evolution. Here we shall use EvoSim, a particularly fast artificial life evolution simulation developed by Russell Garwood (supervisor here) and Mark Sutton (Imperial College London), which has the potential to address all the key aspects of the laboratory system (Fig. 2).

Fig. 2 Modelling evolution in a spatially structured environment. A screenshot of the



EvoSim software, showing spatial variation in the environment (right-hand side) and the evolved spatial distribution of different genotypes (left-hand side, each colour representing a different genotype). This simulation involves approximately 330,000 individual organisms.

The successful candidate will have a strong interest in understanding evolutionary processes and environmental effects upon them. They will have the opportunity to take forward that understanding using some of the most experimentally tractable, yet environmentally relevant systems available, while training in a unique inter-disciplinary environment involving both wet-lab experimental evolution and computational modelling.

References

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3. Fusco D, Gralka M, Kayser J, Anderson A, Hallatschek O (2016) Excess of mutational jackpot events in expanding populations revealed by spatial Luria-Delbruck experiments. *Nat Commun* 7: 12760.
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