Stress in a Nutrient Landscape Results in
Stable Segregation of Selfish and Altruistic Populations

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Abstract:
Landscapes in ecology have a profound influence on the adaption and evolution of competing populations for resources. We are interested in how altruistic populations survive in the presence of selfish individuals in a non-stirred, closed and complex nutrient landscape. Well-stirred (landscape-free) but closed environments have a depressing future, known as the Tragedy of the Commons, when selfish individuals arise in a population. We have shown, using a non-stirred nanofabricated habitat landscape, that altruists and selfish bacteria can coexist, that they can maintain phenotype diversity and avoid the Tragedy of the Commons. However, this avoidance of the tragedy comes at a cost: segregation of the two populations into highly complex spatially distinct regions at many length scales. This emergent spatial segregation of competing populations under stress greatly changes, we believe, our perception of the true sophistication of bacterial response to stress and competition, and has broad implications for the adaptive strategies of higher organisms under stress in complex environments. The Tragedy of the Commons is avoided at the cost of segregation.

Summary of Research:
What do we learn from this experiment? First, we think we should move away from the prisoners dilemma terminology of “defectors” and “cooperators” with the pejorative implications for the defectors, although our terminology of “selfish” and “altruists” is equally pejorative. In reality, probably both strains of altruists and selfish bacteria are necessary for the stable existence of the species in the presence of the complex and ever-changing nutrient landscape that is presented outside the confines of the microbiology laboratory. The facile change of the genome from the wild-type altruist genome JEK1036 to the rpoS mutant JEK1033 in a few days under stress with a 48 bp repeat of the adjoining sequence in the rpoS gene surely indicates that the GASP phenotype is programmed in, and is not a random event.

We have shown here that the growth advantage adapted strain phenotype does not result in a Tragedy of the Commons ecological disaster as long as the nutrient landscape is allowed to develop and is complex in topology, although admittedly ours is a very simple form of complexity.

The real test of the general importance of this result will be the extrapolation of these experiments to true 2 and 3-D nutrient landscapes and the use of eucaryotic cells in addition to bacteria. Ultimately, we believe that by learning the rules of engagement and observing the dynamics and steady-state solutions that competing communities develop as they cope with a rough fitness landscape that we will gain insight into a fundamentally analog systems problem which cannot be coded on conventional digital computers: how do agents improve fitness while competing for scarce resources? Do meta-populations follow the logic of Game Theory or do they find solutions that are illogical from a game theory perspective yet maximize strain fitness?
Figure 1: Schematic of a 2-level nutrient landscape device. The left-hand side habitat patch is a “black” one with no nanochannels open, the right-hand side one is a “white” patch with full openings. Nutrient and lysis molecules (due to the death of bacteria) are denoted by brown and green spheres respectively.