The Evolution of Multicellularity

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Abstract

Major evolutionary transitions in Darwinian individuality are central to the emergence of biological complexity. The key to understanding the evolutionary transition to multicellularity is to explain how a collective becomes a single entity capable of self-reproduction – a Darwinian individual. During the transition from single cells to multicellular life, populations of cells acquire the capacity for collective reproduction; however, the selective causes and underlying mechanisms are unclear. This thesis presents long-term evolution experiments using a single-celled model system to address fundamental questions arising during the evolution of multicellularity. Populations of the cooperating bacterium *Pseudomonas fluorescens* were subjected to experimental regimes that directly selected on the capacity for collectives to differentially reproduce – an essential requirement for the evolution of collectives by natural selection.

A crucial stage during an evolutionary transition to multicellularity occurs when the fitness of the multicellular collective becomes 'decoupled' from the fitness of its constituent cells. Before this stage, any differences in collective fitness are due to selection at the cellular level. In the present study, collectives that competed to reproduce via a cooperative propagule cell attained high levels of cooperation and also reached high levels of collective fitness. However, these improvements were shown to be a consequence of selection acting at the cell-level. In contrast, Darwinian individuality emerged in collectives that reproduced via a primitive life cycle that was fueled by conflict between cooperating cells and cheating cells that did not bear the cost

of cooperation. Cheats were analogous to a germ line, acting as propagules to seed new collectives. Enhanced fitness of evolved collectives was attributable to a property selected at the collective-level, namely, the capacity to transition through phases of the life cycle, and was not explained by improvement in individual cell fitness. Indeed, the fitness of individual cells declined.

In addition to providing the first experimental evidence of a major evolutionary transition in individuality, the work presented in this thesis highlights the possibility that the prevalence of complex life cycles among extant multicellular organisms reflects the fact that such cycles, on first emergence, had the greatest propensity to participate in Darwinian evolution.

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Table of Contents

List of Figures

List of Tables