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Theoretical investigation into the origins of multicellularity.

A thesis presented in partial fulfilment of the requirements for the degree of

PhD

in

Theoretical Biology

at Massey University, Albany, New Zealand.

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2015

Abstract

Evolution of multicellularity is a major event in the history of life. The first step is the emergence of collectives of cooperating cells. Cooperation is generally costly to cooperators, thus, non-cooperators have a selective advantage. I investigated the evolution of cooperation in a population in which cells may migrate between collectives. Four different modes of migration were considered and for each mode I identified the set of multiplayer games in which cooperation has a higher fixation probability than defection. I showed that weak altruism may evolve without coordination among cells. However, the evolution of strong altruism requires the coordination of actions among cells.

The second step in the emergence of multicellularity is the transition in Darwinian individuality. A likely hallmark of the transition is fitness decoupling. In the second part of my thesis, I present a method for characterizing fitness (de-)coupling which involves an analysis of the correlation between cell and collective fitnesses. In a population with coupled fitnesses, this correlation is close to one. As a population evolves towards multicellularity, collective fitness starts to rely more on the interactions between cells rather than the individual performance of cells, so the correlation between particle and collective fitnesses decreases. This metric makes it possible to detect fitness decoupling.

I used the suggested metric to investigate under which conditions fitness decoupling occurs. I constructed a model of a population defined by a linear traits-to-fitness function and used this to identify those functions that promote fitness decoupling. In this model, the fitness correlation is equal to the cosine of the angle between the gradients of fitnesses. Therefore, my results allow an estimation of the fitness (de-)coupling state before selection takes place.

In the third section of my thesis, the accuracy of this estimation was tested on available experimental data and using a model simulating an experimental selection regime, which featured non-linear traits-to-fitness functions. The results obtained from the estimation of fitness correlations showed a close approximation to the fitness correlation calculated from experimental data and from simulations in a range of selection regimes.

Acknowledgements

I would like to thank my supervisor, Distinguished Professor Paul B. Rainey for the opportunity to work on the exciting project concerning the fundamental questions of the biology; for his inspiration and for teaching me the high standards of science.

I am thankful for financial support from the Marsden Fund Council from government funding administered by the Royal Society of New Zealand and the New Zealand Institute for Advanced Study.

I thank my collaborators Dr. Katrin Hammerschmidt, Dr. Caroline Rose, Dr. Chaitanya S. Gokhale, Dr. Julian Garcia and my co-supervisors Dr. Eric Libby and Dr. Prof. Thomas Pfeiffer for sharing their scientific experience and the wisdom of life.

I thank Dr. Prof. Arne Traulsen and his group for fruitful collaboration during my stay in Max Planck Institute for Evolutionary Biology.

To these who read and commented drafts of this thesis: Dr. Saumya Agrawal, Dr. Benedikt Bauer, Dr. Prof. Cassandra Extavour, Dr. Weini Huang, and Dr. Jorge Peña, thank you for suggestions, which enormously helped me to improve the text.

I thank my colleagues in Rainey lab, especially my office-mates Yeserin Yildirim and Yunhao Liu for their support.

I thank David and Theresa Terry for their hospitality and help with settling down in New Zealand.

I also thank my friends Anton Potkalov, William Turner, Amber Milan, Alex Budny and Mark Caubo.

My teachers: Dr. Prof. Oliver Savchenko, Dr. Tatyana Baturina, Dr. Prof. Grigoriy

Dymshits and Dr. Vladimir Kharitonov, thank you for nurturing my passion for science.

Thank you, Dr. Prof. Sandra Rossie for encouraging me to pursue a PhD degree abroad.

To my parents and my grandmother, thank you for your support in my desire to travel to the other side of the world.

The most of all, I am thankful to my beloved wife Tatyana who followed me through the whole journey.

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