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# **Theoretical investigation into the origins of multicellularity.**

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# 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.

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