

# Effects of Migration as Environmental Response on the Evolution of Cooperation

Genki Ichinose, Takaya Arita

*Graduate School of Information Science, Nagoya University*

*genki@alife.cs.is.nagoya-u.ac.jp, arita@nagoya-u.ac.jp*

Altruistic behaviors are common in humans and some other animals, and are essential in the formation of societies. However, the evolution of cooperation is paradoxical, since altruistic traits confers a cost to the actor and a benefit to other individuals and thus natural selection should favor selfish individuals. Evolutionary biologists have developed theoretical frameworks to explain this paradox. One explanation is reciprocal altruism and another one is kin selection. In 1998, Sober and Wilson proposed a modern version of group selection called “multilevel selection” [2]. This idea has attracted great attention because it could incorporate previous various theories for the evolution of cooperation.

Consider a population that is subdivided into groups. An individual in a group including many cooperators gets a higher payoff than in a group including many defectors (between-group selection). A defector gets a higher payoff than a cooperator within the group (within-group selection). Multilevel selection theory shows cooperators evolve when the former selection predominates over the latter selection. Here, one of the most important factors is whether the bias between groups continually exists. In other words, the evolution of cooperation requires a structured population in which cooperators interact more frequently with cooperators and defectors interact more frequently with defectors. These situations can be realized in kin groups. In this sense, multilevel selection is a comprehensive theory covering kin selection as well as group selection.

Pepper and Smuts[1] have proposed environmental feedback as a mechanism for generating such non-random populations. In their models, each individual can detect the condition of its environment, specifically the amount of food in its patch, and it tends to migrate if the food is not enough there. Here we investigate the effects of migration as environmental response. Environmental response is the more basic concept involving the environmental feedback. We introduce the evolution into the model in order to investigate how it affects the population structure.

We constructed agent-based models and conducted evolutionary simulations. We investigated the typical patterns of environmental response. The simulation has shown that cooperation evolves when more altruistic individuals migrate than selfish individuals and also that the founder effect on the process of evolution affects the population structures. In addition, by conducting analysis based on the theory of kin selection, we have confirmed that Hamilton’s rule is satisfied in cases where cooperation evolves. These results have suggested that evolution plays a positive role of assortment between cooperators and defectors and that the evolution of cooperation is promoted in cases where individuals react sensitively to the environmental conditions.

## References

- [1] J.W. Pepper and B.B. Smuts. A Mechanism for the Evolution of Altruism among Non-kin: Positive Assortment through Environmental Feedback. *American Naturalist*, 160: 205–212, 2002.
- [2] E. Sober and D. S. Wilson. *Unto Others, The Evolution and Psychology of Unselfish Behavior*. Harvard University Press, 1998.