

# Emergence of Rock-Paper-Scissors from Intra-specific Competition

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We show how cyclic 'rock-paper-scissors' ecologies can emerge from simpler systems of just two species. We also highlight a counter-intuitive effect in such systems: they behave in such a way as to hide the underlying fitness of their constituents.

Several examples of non-transitive (cyclic) competitions have been described between different biological species, while in others the competition is between morphs of a single species. For the latter case to be stable, diversity must be promoted by individual traits benefiting intra-specific competitiveness.

We present a two-species model in which all individuals possess a heritable trait for intra-specific competitiveness. In our model both species possess heritable traits that face an intra- versus inter-specific trade-off. Analysis and simulation of this model suggests that when interactions are localised, we should expect intermediate phenotypes to be selected against, and to find an abundance of individuals who specialise in either intra- or inter-specific competitiveness. Evolutionary branching in the intra-specific competitiveness trait readily occurs, leading to 'Rock-paper-scissors' and other non-transitive cyclic competition systems, and this might be viewed as a precursor scenario to subsequent speciation. Our model provides a mechanism by which complex cyclic dynamics of three or more species could evolve out of a simpler two-species ecosystem.

Within-species competition also works to balance out any advantage one species may have when competing against another: any rise in the population of a stronger species presents an opportunity for competition between its members, enhancing the stability of the system as a whole. A notable consequence of this is that, in our idealised model at least, the two species have similar population numbers regardless of their underlying fitness level. To put this another way, adding a species-specific toxin to the system does not change the species distribution in the long term: it only changes the proportions of intra- versus inter-specific specialists.