Limited role of spatial self-structuring in emergent trade-offs during pathogen evolution

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Pathogen transmission and virulence are main evolutionary variables broadly assumed to be linked though trade-offs. In well-mixed populations, these trade-offs are often ascribed to physiological restrictions, while populations with spatial self-structuring might evolve emergent trade-offs.

Here, we reexamine a model of the latter kind proposed by Ballegooijen and Boerlijst [1] with the aim of characterising the mechanisms causing the emergence of the trade-off and its structural robustness. Using invadability criteria, we establish the conditions under which an evolutionary feedback between transmission and virulence mediated by pattern formation can poise the system to a critical boundary separating a disordered state (without emergent trade-off) from a self-structured phase (where the trade-off emerges), and analytically calculate the functional shape of the boundary in a certain approximation.

Beyond evolutionary parameters, the success of an invasion depends on the size and spatial structure of the invading and invaded populations. Spatial self-structuring is often destroyed when host are mobile, changing the evolutionary dynamics to those of a well-mixed population. In a metapopulation scenario, the systematic extinction of the pathogen in the disordered phase may counteract the disruptive effect of host mobility, favour pattern formation and therefore recover the emergent trade-off [2].

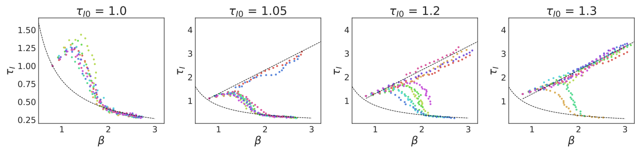

Fig. 1. Evolutionary trajectories of realizations with finite diffusion and fixed initial transmission rate β, for different values of the initial infection period τ_{I0}. The dashed black line shows the expected behaviours: No diffusion $\tau_I = R_0^{\rm ev}/(8\beta)$ and mean-field $\tau_I = \beta +$ constant. The system either displays a behaviour indistinguishable from the $D = 0$ case or follows a curve of steady increase in R_0, as predicted in the mean-field theory. The region where stochastic fluctuations can lead the system to any of the two states stretches to a point in the limit $L \to \infty$.

[1] W. M. Ballegooijen and M. C. Boerlijst, Emergent trade-offs and selection for outbreak frequency in spatial epidemics, Proc. Natl. Acad. Sci. USA **101**, 18246-18250 (2004).

[2] V. Buendía, M. A. Muñoz, and S. Manrubia, Limited role of spatial self-structuring in emergent trade-offs during pathogen evolution, Sci. Rep. **8**, 12476 (2018).