Evolutionary cooperation, an old debate, a new perspective

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Different pathogens spread often in the same host population in parallel. They can interact in different manners: for a short period cooperation between pathogens can lead to faster and larger host occupation [1, 2, 3]. Spanish Flu and HIV are examples of such cases. This cooperation, however, can lead to death of the host population and consequently also pathogens death. Therefore on a long run, the cooperation strategy is not necessary the best.

Here we propose and study an evolutionary game model in order to understand the co-evolutionary dynamics of two co-infecting pathogens, see Fig. 1. They have a common host and the host does not evolve on the same time scale as the pathogens. We consider two kind of disease species. In what follows, we denote the state of a pathogenic agent with X_y, where $X \in \{A, B, a, b, AB, ab, Ab, aB\}$ denotes the disease state of the pathogen, and $y \in \{C, D\}$ denotes its strategy, instead. In particular, agents (pathogens) accumulate a *payoff*, Π, based on the history of their contagion records. We assume if the host is populated by a cooperator infection from another disease is possible. If the host is populated by a defector there will be no infection at all. This gives rise to two main scenarios: The first is when the disease infects an empty host with probability p. In this scenario, the pathogen does not meet any resistance and all the host resources are available to him. For simplicity, we consider the amount of total resources available in the host equal to one. Therefore, when the pathogen enters into an empty host it receives a payoff equal to one irrespective of its type and strategy. When the host is already occupied by another disease and the probability of infecting is q things become a bit more complicated. More specifically, as shown in panel b, there are four possible combinations of pairs of strategies: (C, C), (C, D), (D, C) and (D, D) corresponding to different payoffs. As commented above, a cooperator pathogen does not oppose any resistance to the contagion by another disease and will share the host resources with it. A defector entering a host populated by a cooperator will seize the majority of available resources. Defining the *payoff*s, we first show under which conditions cooperation may or may not be a meaningful strategy in a mean field approximation. Then we show how underlying transmission and contact networks may promote both the spreading and the emergence of cooperation.

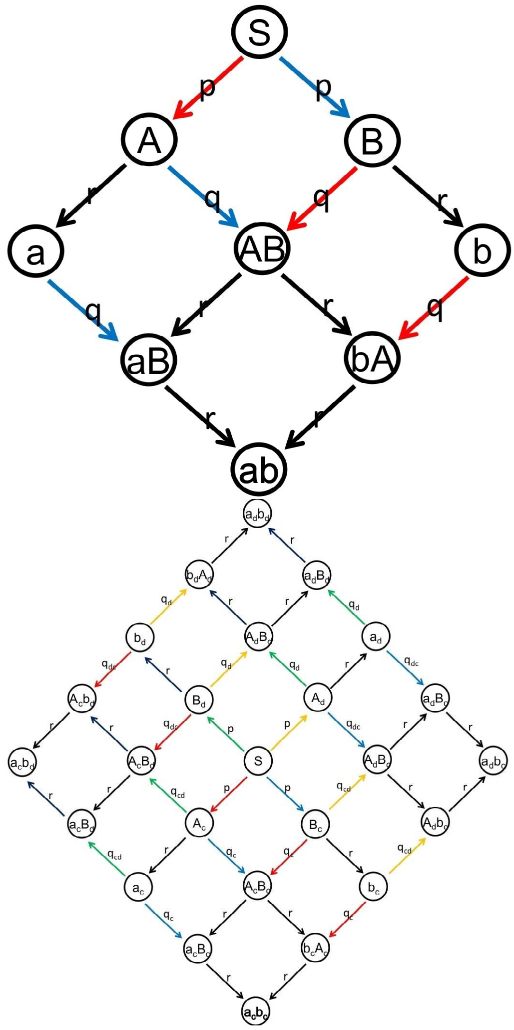

Figure 1: Schematic representation of all the possible transitions among compartments in the multi disease propagation of diseases [A] and [B] while A) only either cooperation or defection is present, B) cooperation and defection are both present. Parameters r,p,q are representing recovery, first and secondary infection rates.

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