Eco-evolutionary dynamics of temperate phages in periodic environments

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I. Introduction

- Temperate phages can either lyse their host or integrate their genome with that of the host, forming lysogens.
- Reproductive success of these two strategies depends on density of susceptible hosts (Figure 1) – low host density environments favor lysogeny while high host density environments favor lysis [1,2].
- While the basic reproduction number provides a framework to define the fitness of each strategy in the short-term, we lack a framework to analyze the long-term fitness of viral strategies in fluctuating environments.

We developed a differential equation model with a periodic filter to simulate resource-host-virus dynamics in conditions with fluctuating host availability and viral mortality.

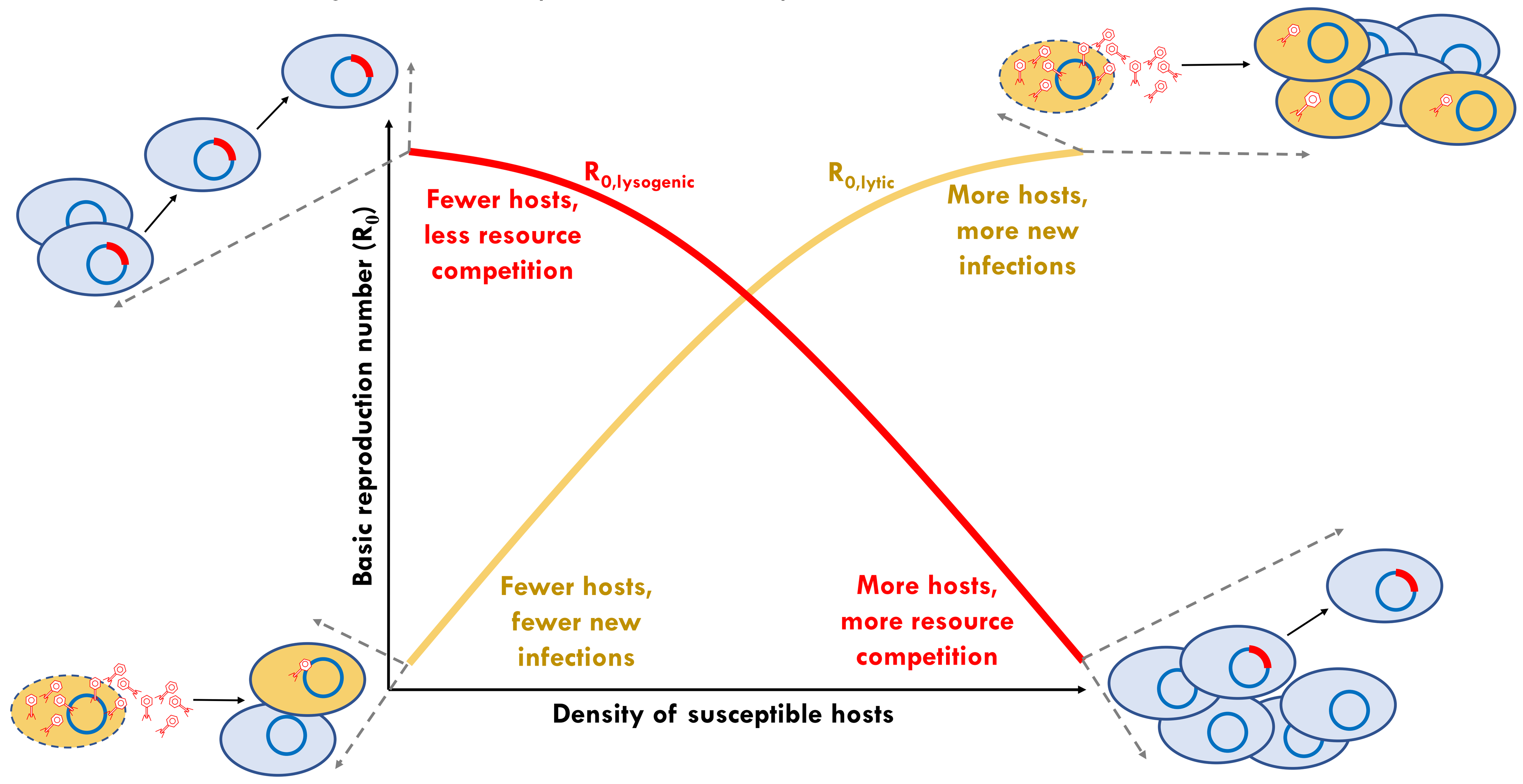

Figure 1 Basic reproduction numbers (R_0) for lytic and lysogenic strategies as functions of host density. Reproduced with modifications from [3]. R_0 is the average number of new infected cells produced by a single infected cell.

II. Model framework to simulate periodic fluctuations in host availability and viral mortality

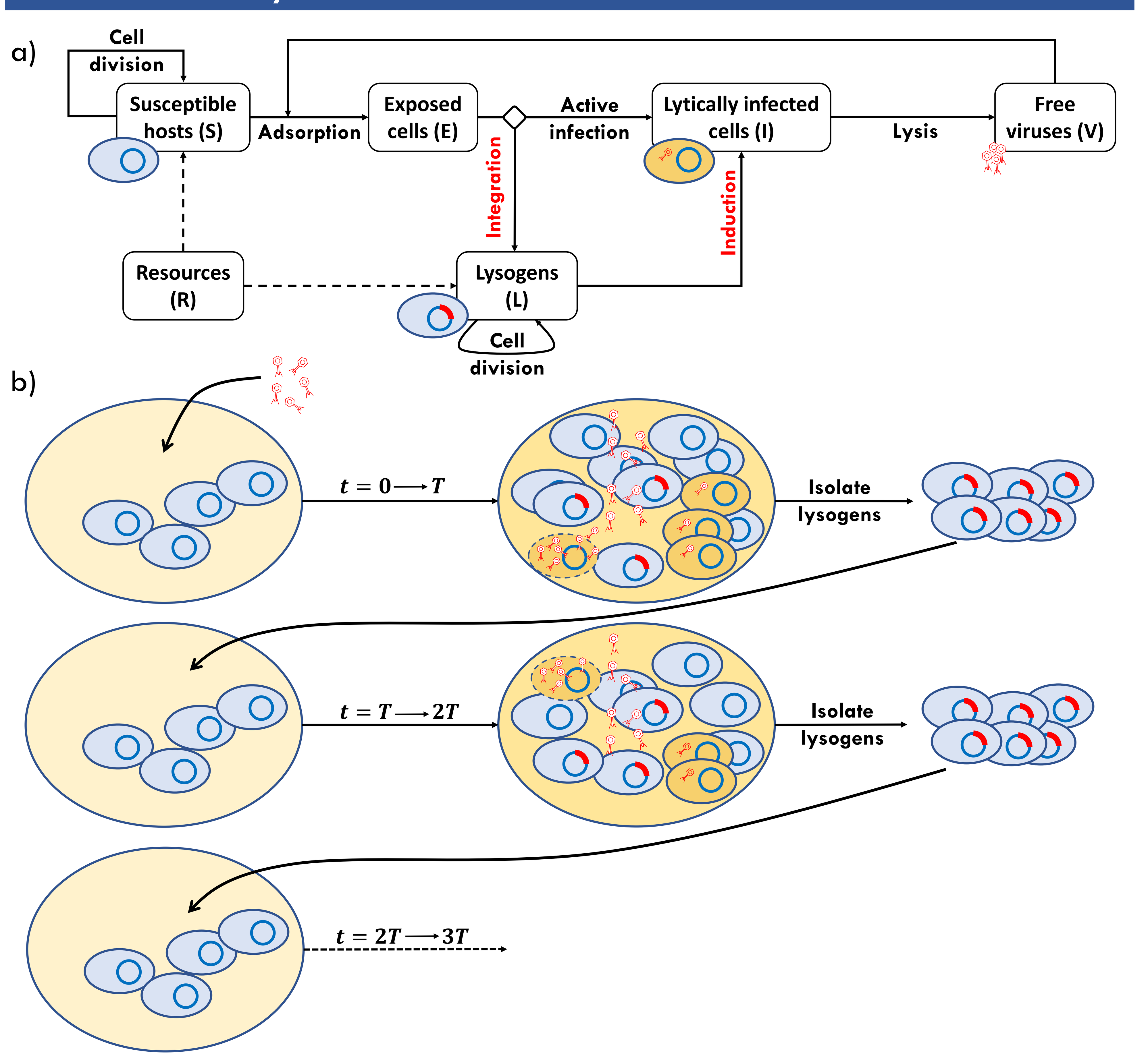

Figure 2 Schematics of (a) resource explicit SEILV model used to simulate resource-host-virus dynamics and (b) serial passage framework to impose selection for lysogens.

III. Host cell density affects the evolutionary dynamics of temperate phages

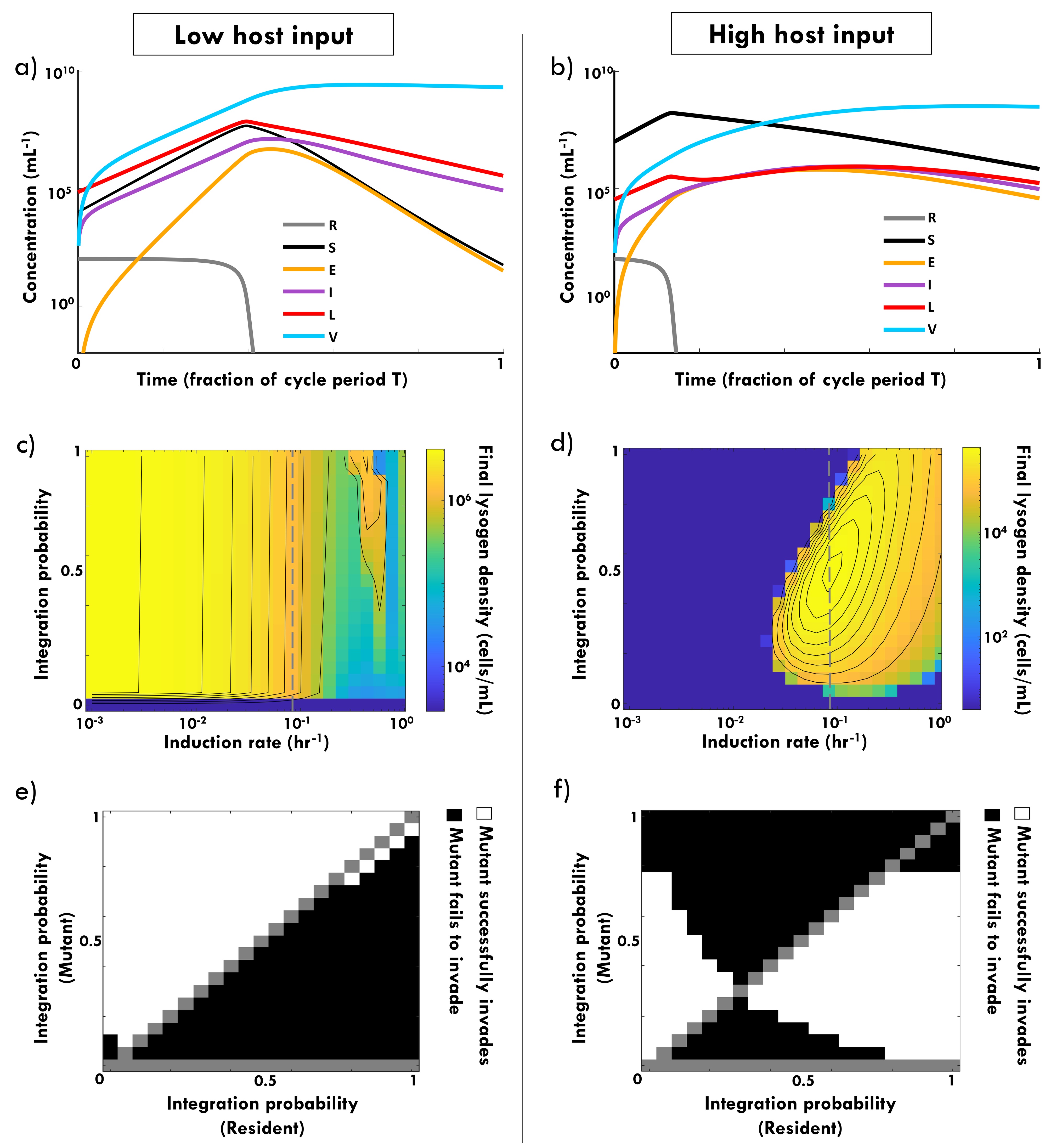

Figure 3 (a,b) Population dynamics on the periodic attractor for (a) low and (b) high susceptible host inputs. (c,d) Final steady state lysogen densities for a system with one host and one virus, for different values of integration probabilities and induction rates. Since only lysogens transfer between passages, final lysogen densities can be thought of as proxies for the long-term reproductive success of the virus. (e,f) Pairwise invasibility plots for resident mutant pairs with different integration probabilities for a fixed induction rate (grey dashed line in c,d). White represents positive invader growth rate and black denotes negative invader growth rate.

IV. Conclusions and future directions

- Our model provides a general framework to study eco-evolutionary dynamics of temperate viruses in fluctuating environments: we can change the short-term selection pressure by varying host/resource input and the long-term selection pressure by varying the filter and passage cycle duration.
- When host input is low, viruses evolve towards high integration probabilities and therefore towards lysogenic strategies.
- When host input is high, viruses evolve to intermediate integration probabilities and therefore to more intermediate temperate strategies.

Next steps:

- Incorporating effects of cellular multiplicity of infection to accurately model high virus-host ratio conditions.
- Exploring metrics to evaluate long-term fitness for different combinations of short-term and long-term selection pressures

References

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[3] Correa, Howard-Varona, Coy, Buchan, Sullivan & Weitz (2021). Revisiting the rules of life for viruses of microorganisms. *Nature Reviews Microbiology*.