Population Dynamics of Temperate Phage and the Potential Emergence of Phage-Host Coalitions

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I. Introduction

What role do temperate phages play in competing lysogen populations?

A "buffer" to defend against invasion?

A "weapon" to clear space for invasion?

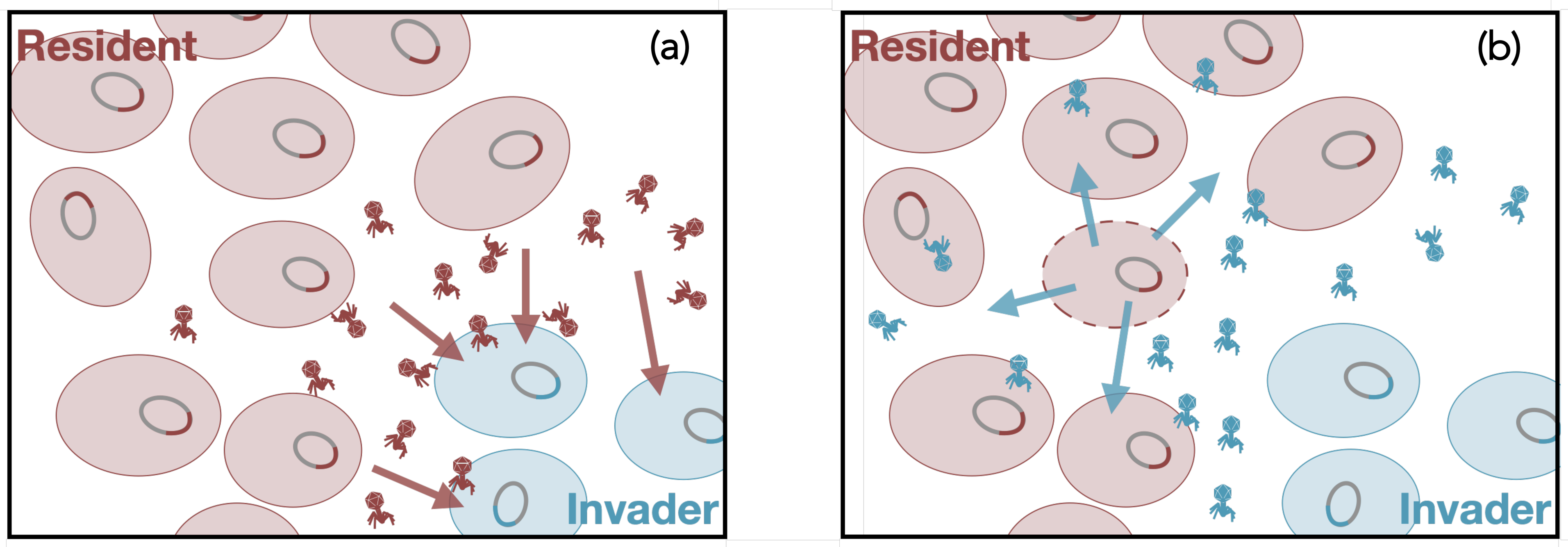

Figure 1. Two roles of temperate phages when lysogens are in competition. (a) Temperate phages are released through spontaneous induction, preventing the invasion of an opposing susceptible lysogen population. **(b)** Temperate phages can lyse opposing lysogens which clears space and reduces competition. In both cases, large numbers of free phages are released, proliferating the "buffer" or "weapon" through subsequent rounds of lytic infections.

II. Model system

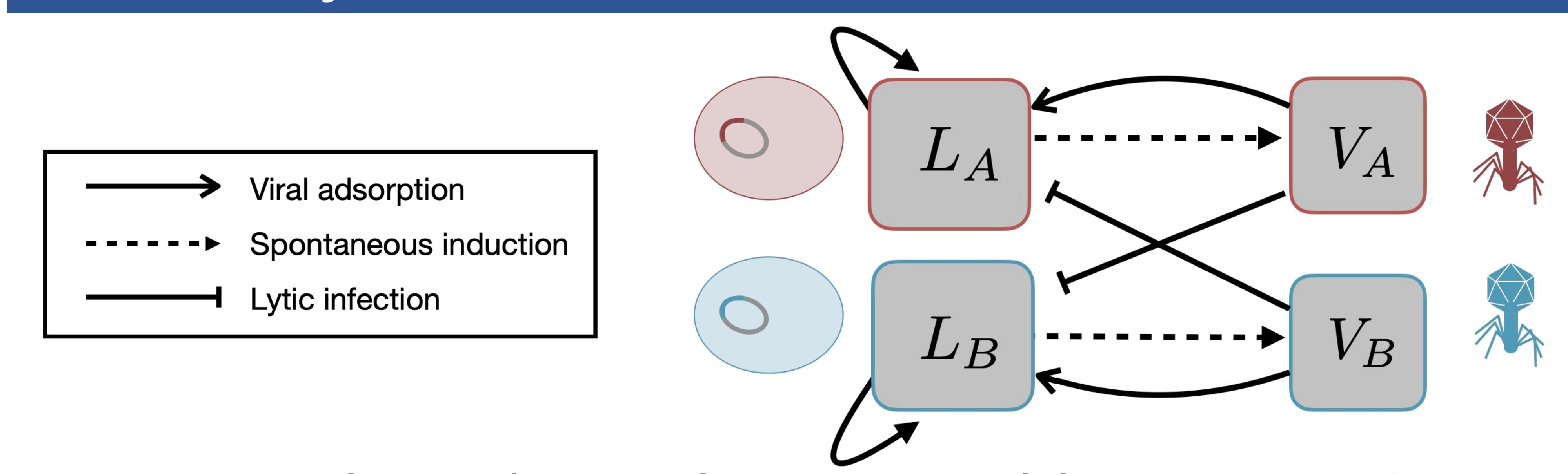

Figure 2. Nonlinear dynamical systems model: temperate phages, V_A and V_B, with their lysogenized hosts, L_A and L_B. Lysogens spontaneously induce at rates slower than lytic infections (dashed arrows), leaving small pools of free phages. These temperate phages can adsorb to their corresponding lysogens (solid arrows) and predate on opposing lysogens via lytic infection (blunt arrows).

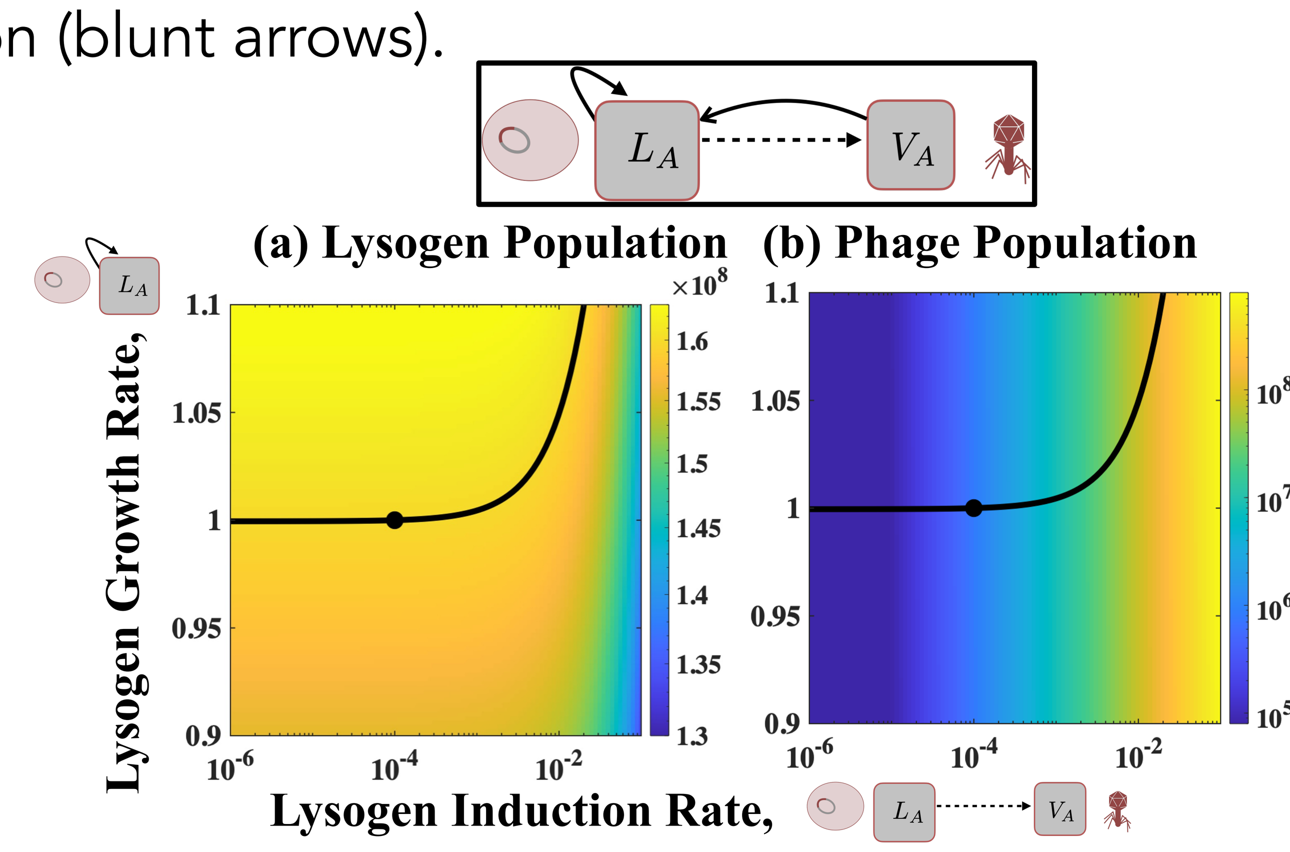

Figure 3. Steady-state trade off between growth and induction. (a) For the steady-state lysogen population to remain constant, the growth rate must increase with increasing induction rate (black line). **(b)** The steady-state phage population increases with increasing induction. We perform invasion analysis from this growth-induction trade off to show the role of free phage given a fixed lysogen population density.

III. Results

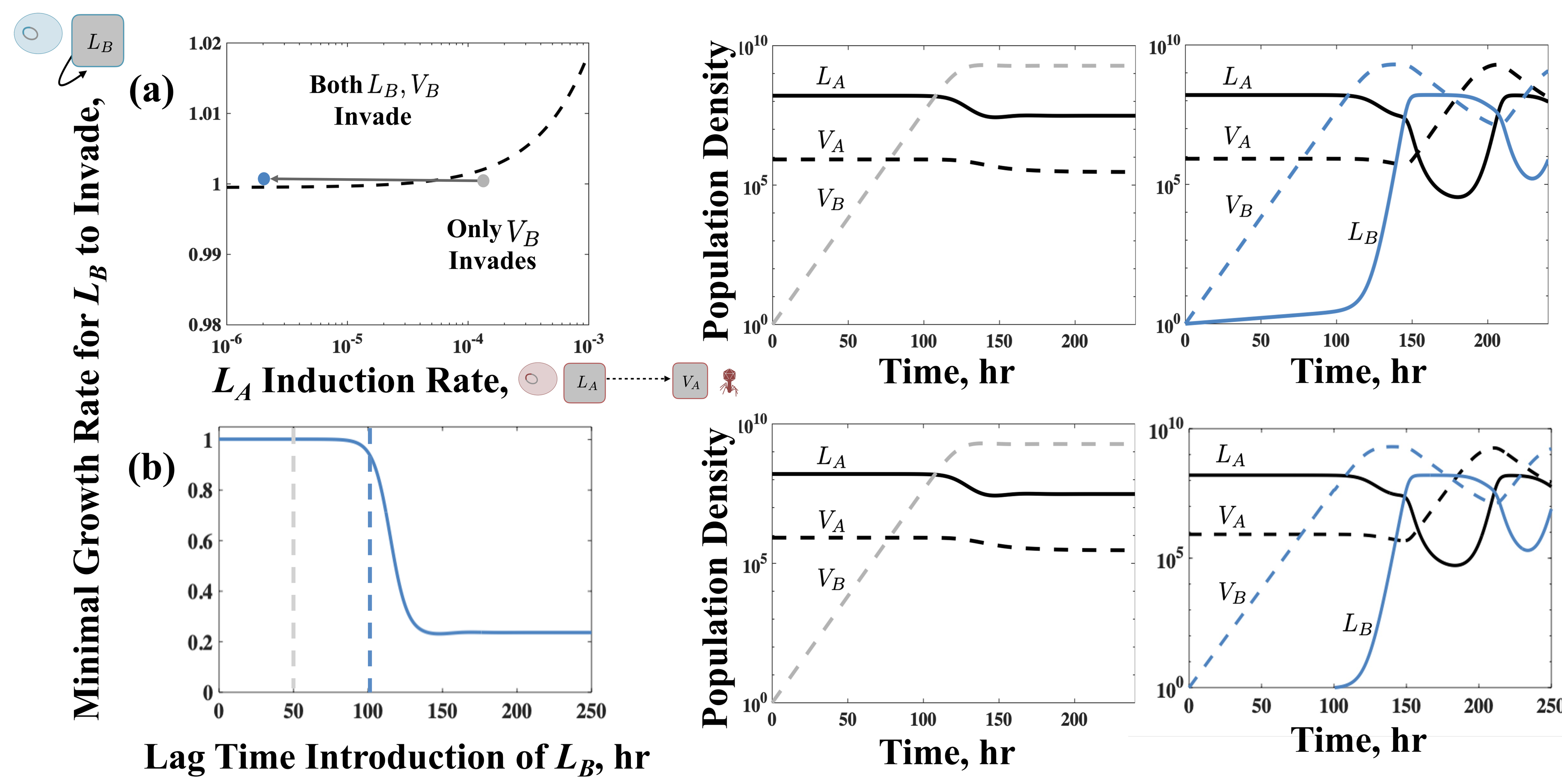

Figure 4. "Buffers" and "weapons" in a well-mixed model. (a) The minimal growth rate required for L_B to invade when L_A is at the steady-state growth-induction trade off (left). V_A lyses L_B, preventing it from invading (gray), but L_B can invade when L_A induction rate is lower (blue). **(b)** Effective minimal growth rate required for L_B to invade (left). V_B lyses L_A, decreasing the population over time. L_B cannot invade at 50 hours post (gray) introduction of V_B but can after 100 hours (blue).

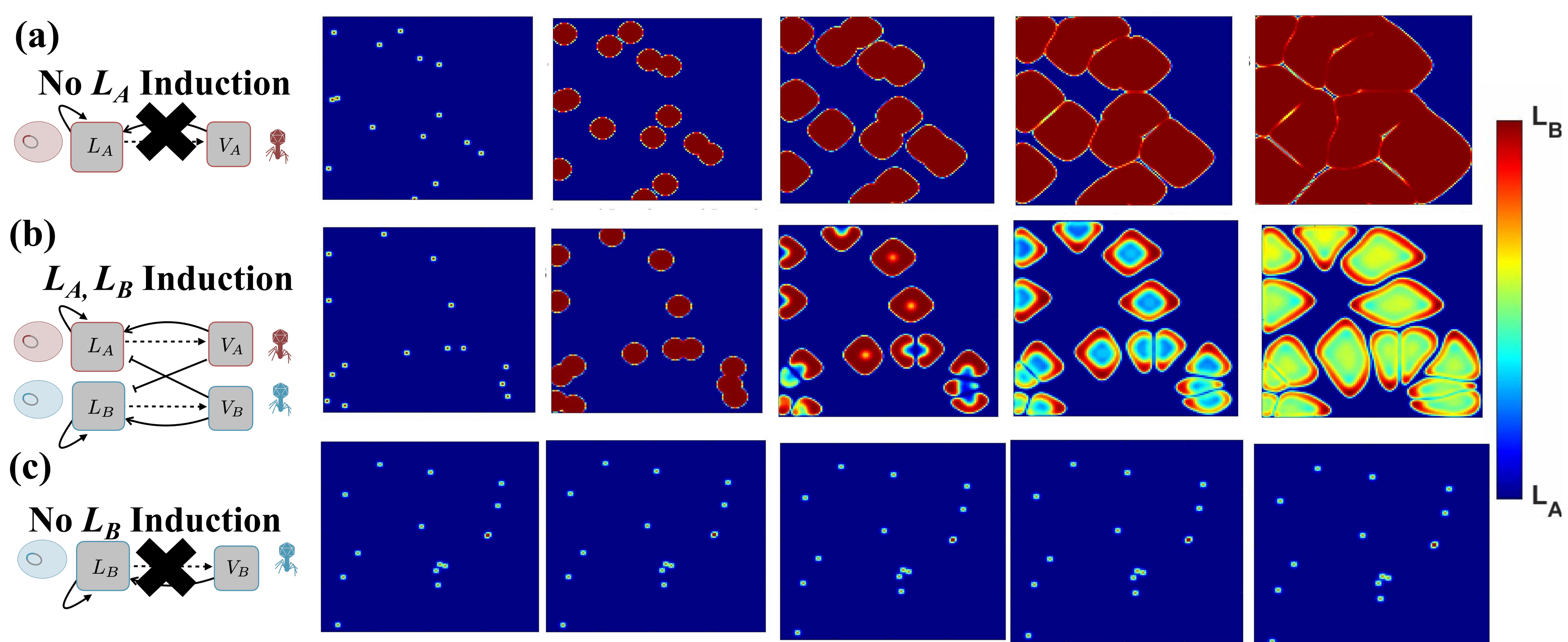

Figure 4. "Buffers" and "weapons" in a spatial model. Invasion dynamics in a 2D grid (6 mm x 6 mm) shown at: 0, 24, 72, 120, 200 hours. With LA induction **(a)**, LB colony expansion is inhibited compared to without LA induction **(b)**. Invasion dynamics without LB induction **(c)** is unsuccessful.

IV. Conclusions

Phages act in cahoots with hosts in competition:

1. a "buffer" against invasion
2. "weapons" to deploy during invasion

Future Directions:

1. Steady-state analysis for coexistence
2. Phase separation and an emergence of a length scale

References

[1] Basso, Jonelle, et al., Buchan, Alison. "Genetically similar temperate phages form coalitions with their shared host that lead to niche-specific fitness effects." *The ISME journal* 14.7 (2020): 1688-1700.
[2] Harrison, Ellie, and Michael A. Brockhurst. "Ecological and evolutionary benefits of temperate phage: what does or doesn't kill you makes you stronger." *BioEssays* 39.12 (2017): 1700112.