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?

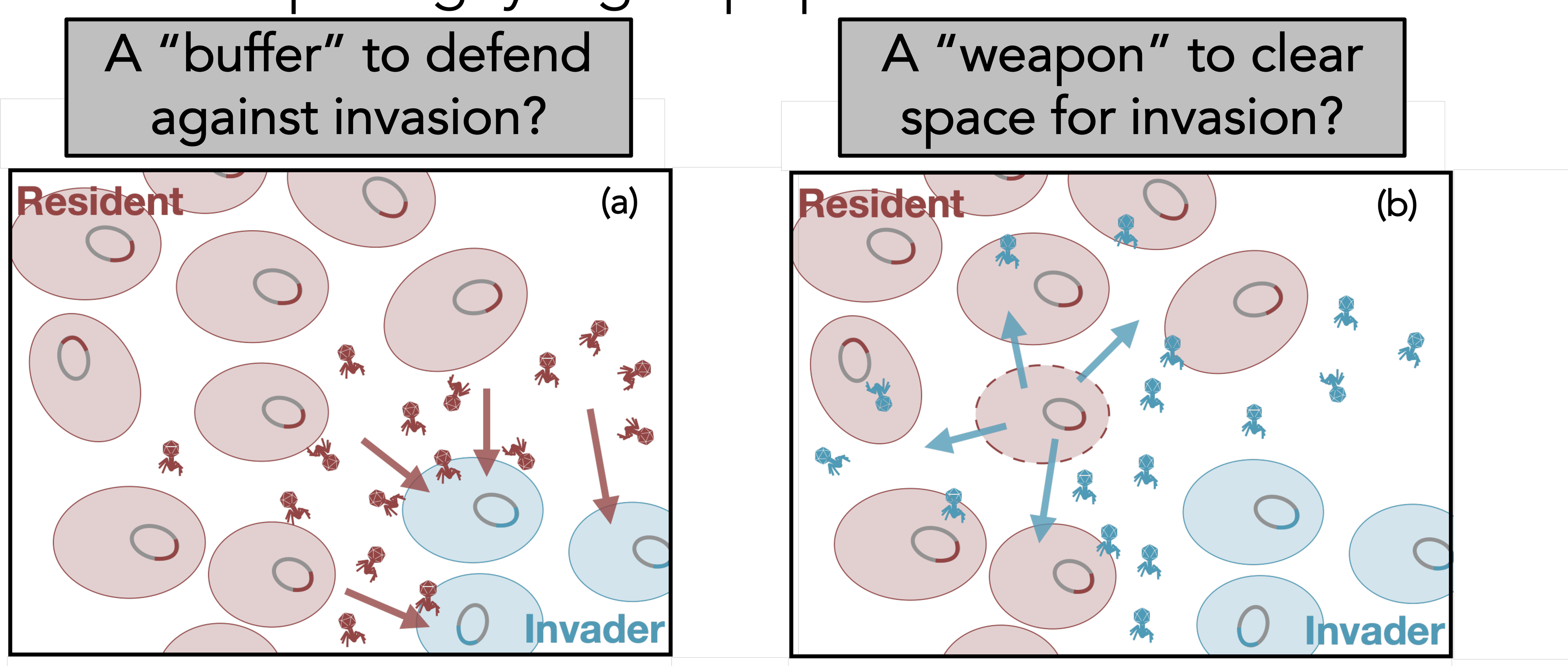

Figure 1. Two roles of temperate phages when lysogens are in competition. (a) Temperate phages are released through spontaneous induction, preventing the invasion of an opposing susceptible lysogen population. (b) Temperate phages can lyse opposing lysogens which clears space for invasion. In both cases,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

II. Model system

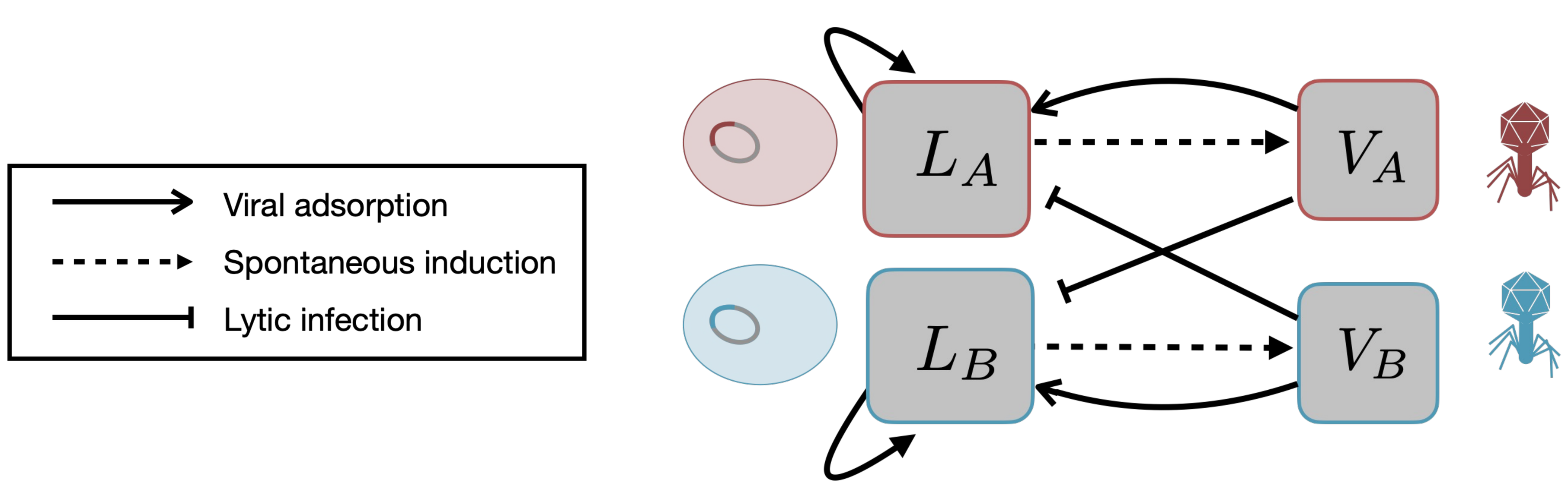

Figure 2. Nonlinear dynamical systems model: temperate phages, V_A and V_B, with their lysogenized hosts, L_A and L_B. Lysogens spontaneously induce (dashed arrows), leaving small pools of free phages. These temperate phages can adsorb to their corresponding lysogens (solid arrows) and lyse opposing lysogens (blunt arrows).

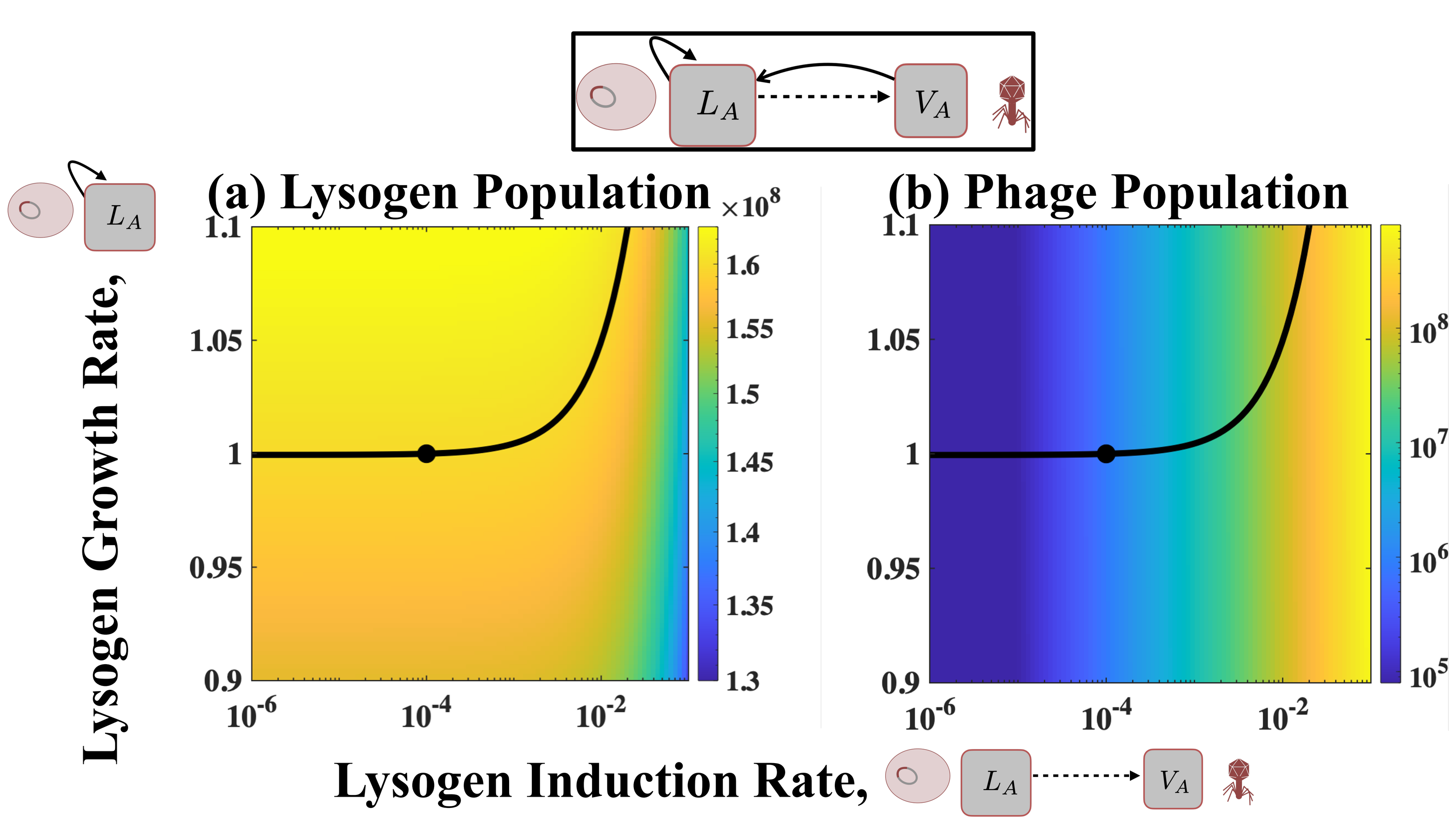

Figure 3. Steady-state trade off between growth and induction. (a) For the steady-state lysogen population to maintain a constant population size, larger induction rates must be compensated with larger growth rates (black line). (b) The steady-state phage population increases with increasing induction. 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

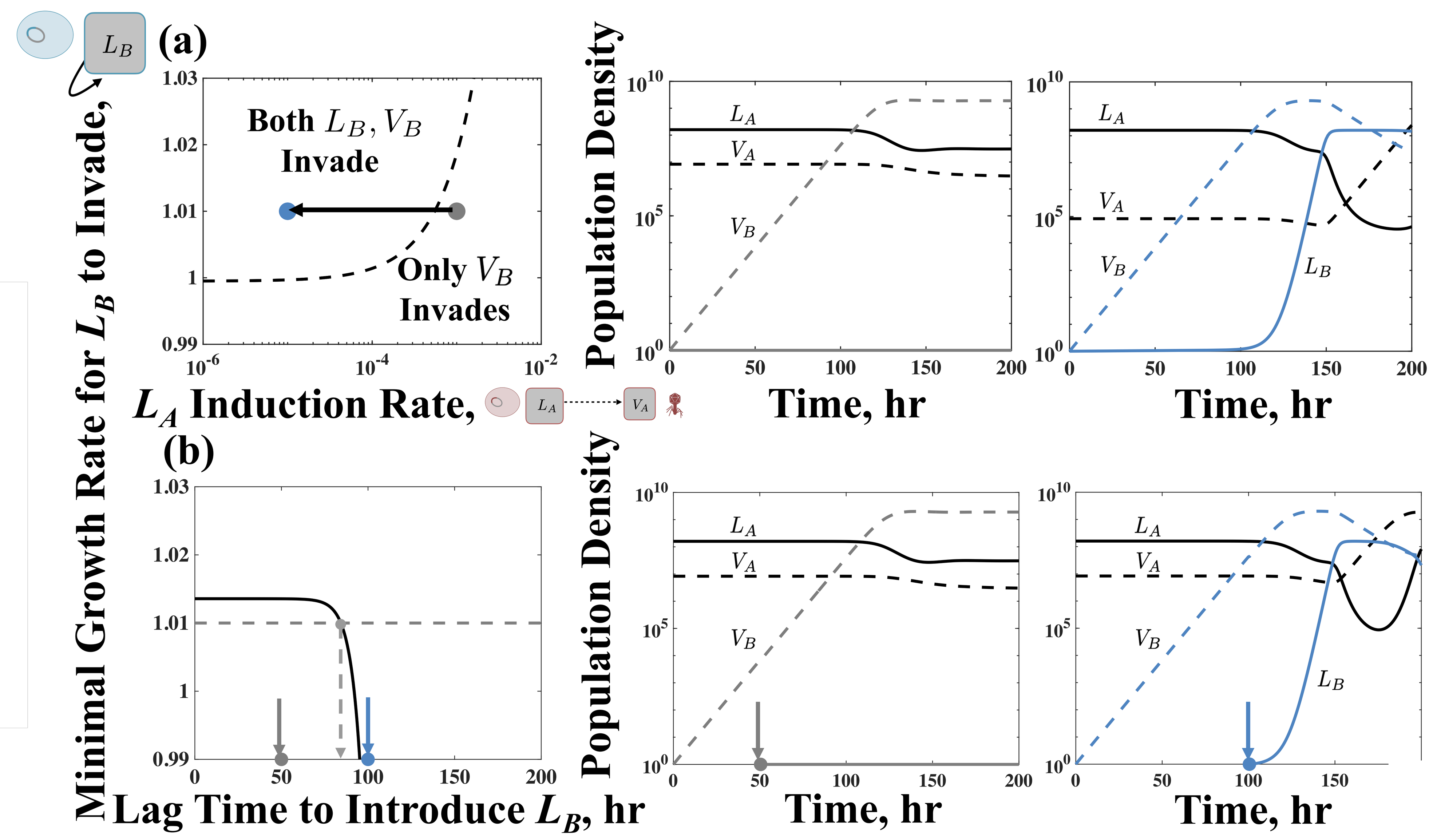

Figure 4. "Buffers" and "weapons" in a well-mixed model. (a) The minimal growth rate required for L_B to invade when L_A is at the steady-state growth-induction trade off (left). V_A lyses L_B, preventing it from invading (gray), but L_B can invade when L_A induction rate is lower (blue). (b) Effective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

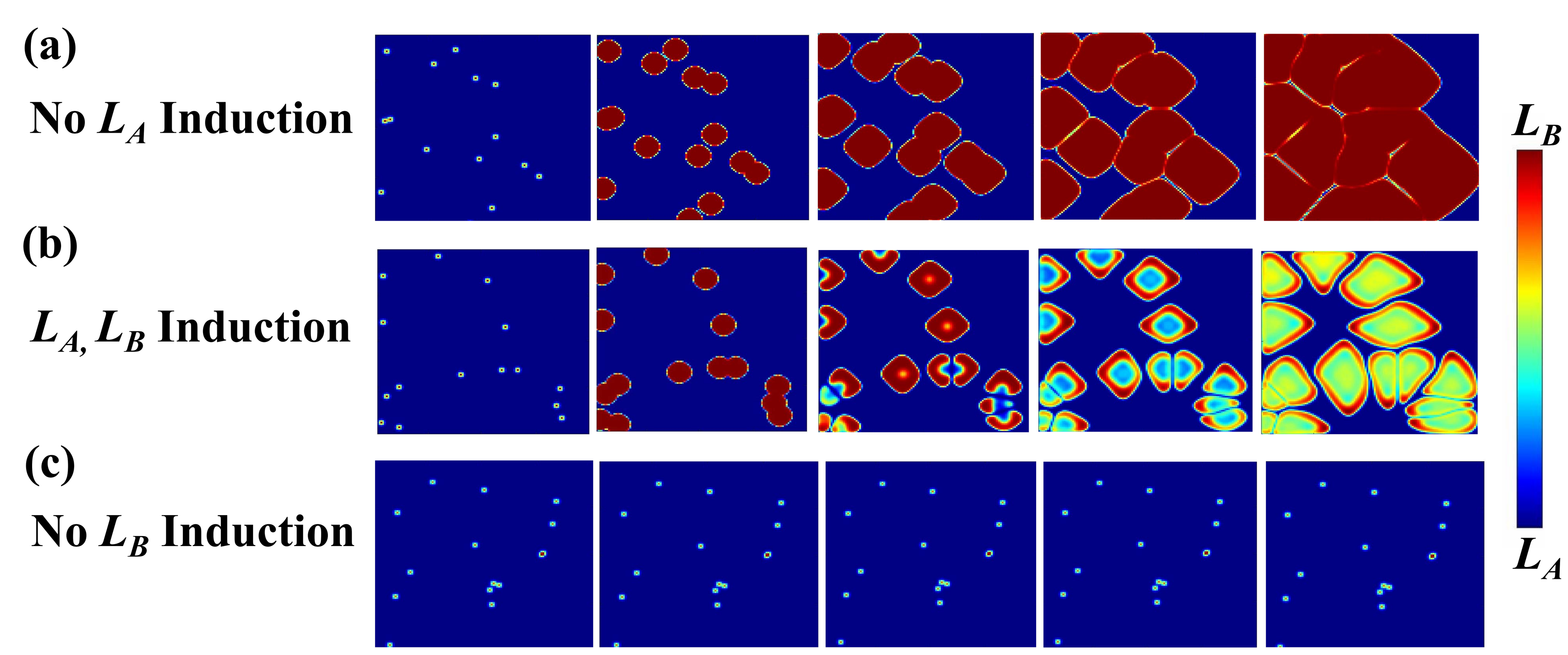

Figure 4. "Buffers" and "weapons" in a spatial model. Invasion dynamics in a 2D planar grid (6 mm x 6 mm) shown at: 0, 24, 72, 120, 200 hours. Without L_A induction (a), L_B colonies expand and dominate over L_A. Here, L_A lacks the V_A buffer to defend itself. With both L_A, L_B induction (b), the expansion of L_B is inhibited by V_A (produced from L_A induction). Without L_B induction (c), L_B lacks a weapon and cannot invade.

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.