Compositional memory matters for early molecular systems

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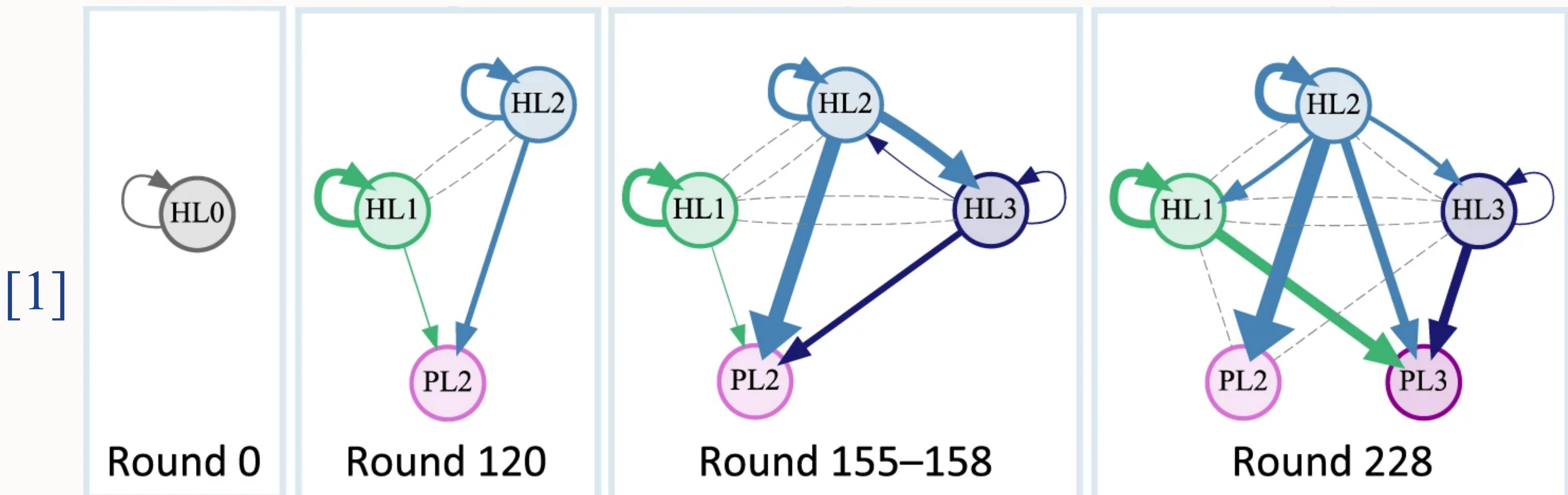
Evolution of complexity

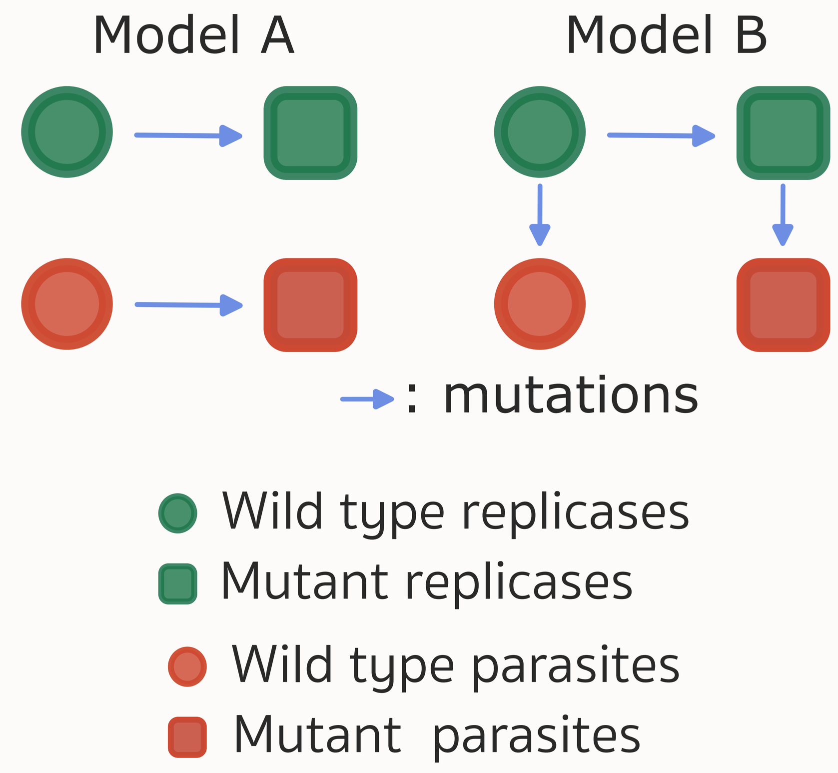
Compartmentalization allows **longer and more complex sequences** to appear and survive against parasites [1].



Models for mutations

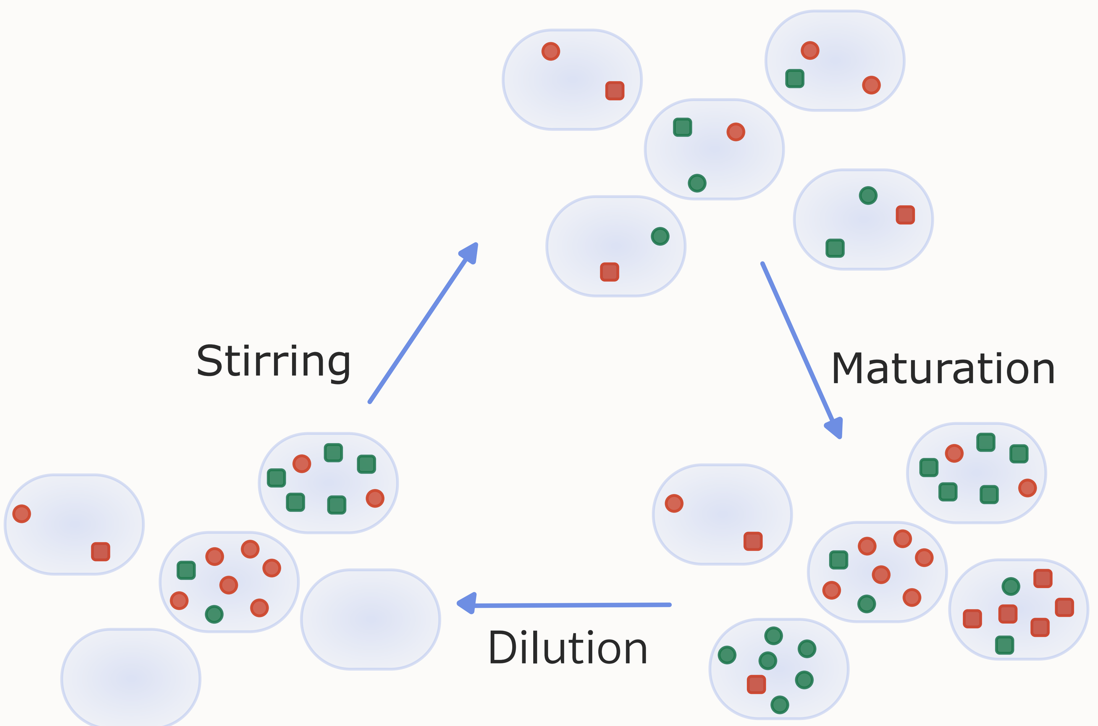
Model A : From WT replicases (resp. parasites) to mutant replicases (resp. parasites)

Model B : From WT replicases to WT parasites or to mutant replicases. From mutant replicases to mutant parasites.



Transient compartmentalization with stirring

We add stirring to **transient compartmentalization dynamics** [1-3]



Maturation

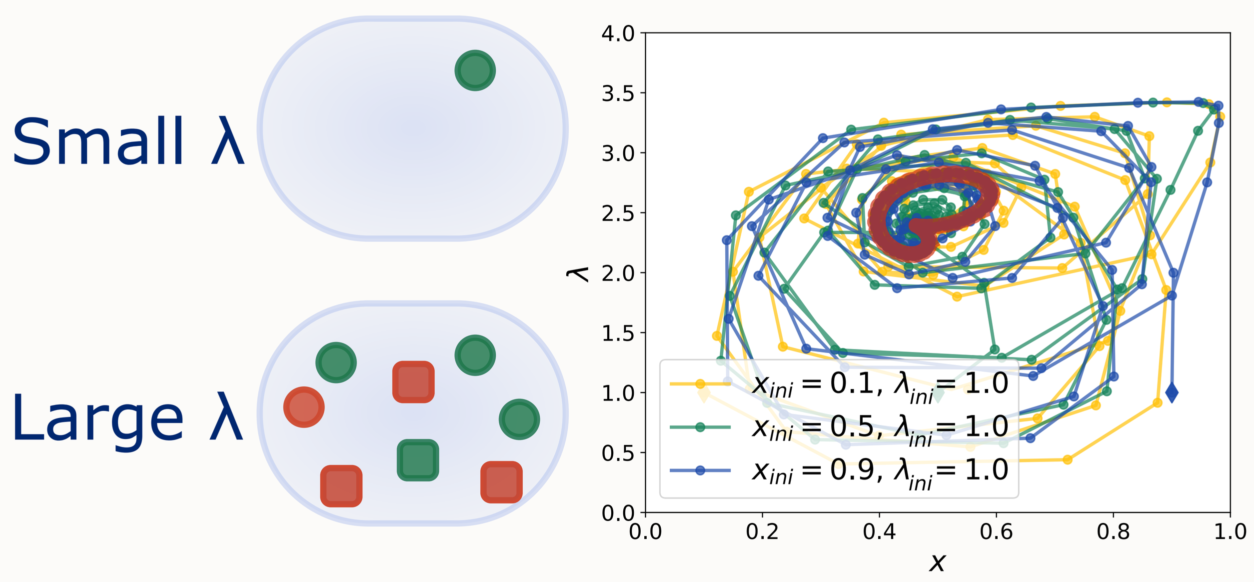
$$\langle \overline{m}_0^{(i)} \rangle = \lambda x_0^{(i)} + K_r \mathbb{P}\,(m_0^{(i)} \text{takes over})$$

Dilution

$$\lambda^{(i)} = \frac{1}{d} \sum_{\boldsymbol{m},\boldsymbol{y}} \overline{n}^{(i)}(\boldsymbol{m}^{(i)},\boldsymbol{y}^{(i)}) P_\lambda(\boldsymbol{m}^{(i)},\boldsymbol{y}^{(i)} | \boldsymbol{x}^{(i)},\boldsymbol{z}^{(i)})$$

Stirring

$$\hat{x}_0^{(i)} = \frac{(1-s)\overline{m}_0^{(i)} + s\,\langle \overline{m}_0 \rangle}{(1-s)\overline{n}^{(i)} + s\,\frac{\langle \overline{n} \rangle}{d}}$$

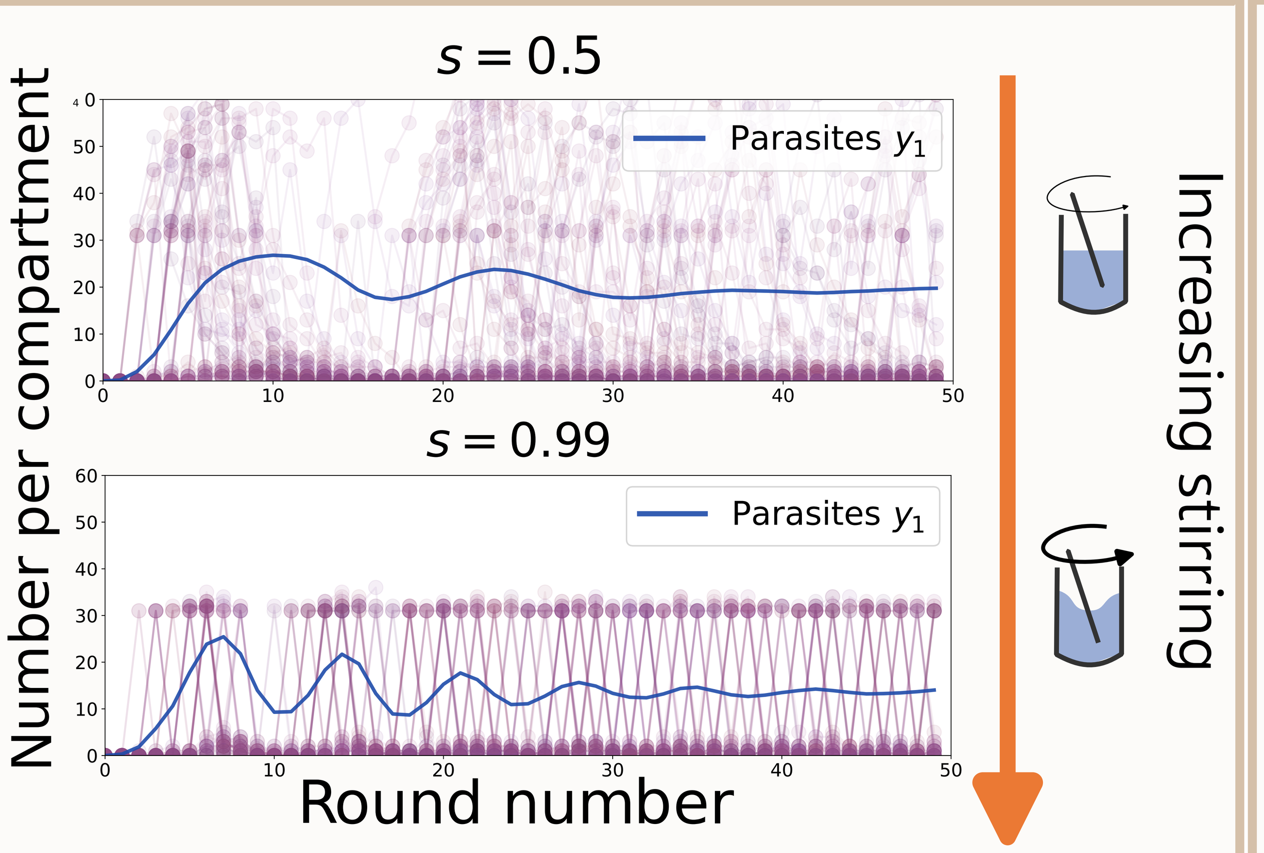


Number of individuals in a compartment drawn according to a Poisson distribution of parameter **λ ~ K/d.**

Composition at compartment level

A **weaker stirring** corresponds to a more **heterogeneous population** and keeps track of the **history** of compartments [4].

In particular, the **content λ** of the compartments has a **larger variability** (proportional to *1-s*).

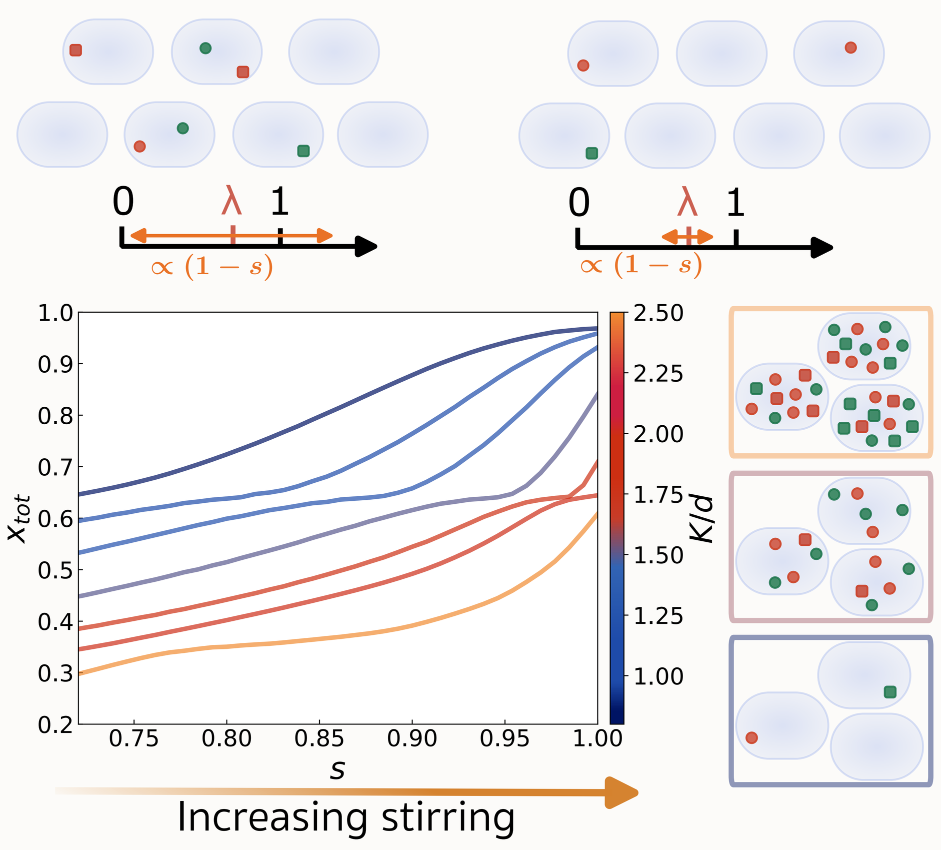


Stirring favors replicases

Stronger stirring and **small λ** isolate parasites, which **cannot replicate** alone.

This leads to **increasing the fraction of replicases.**

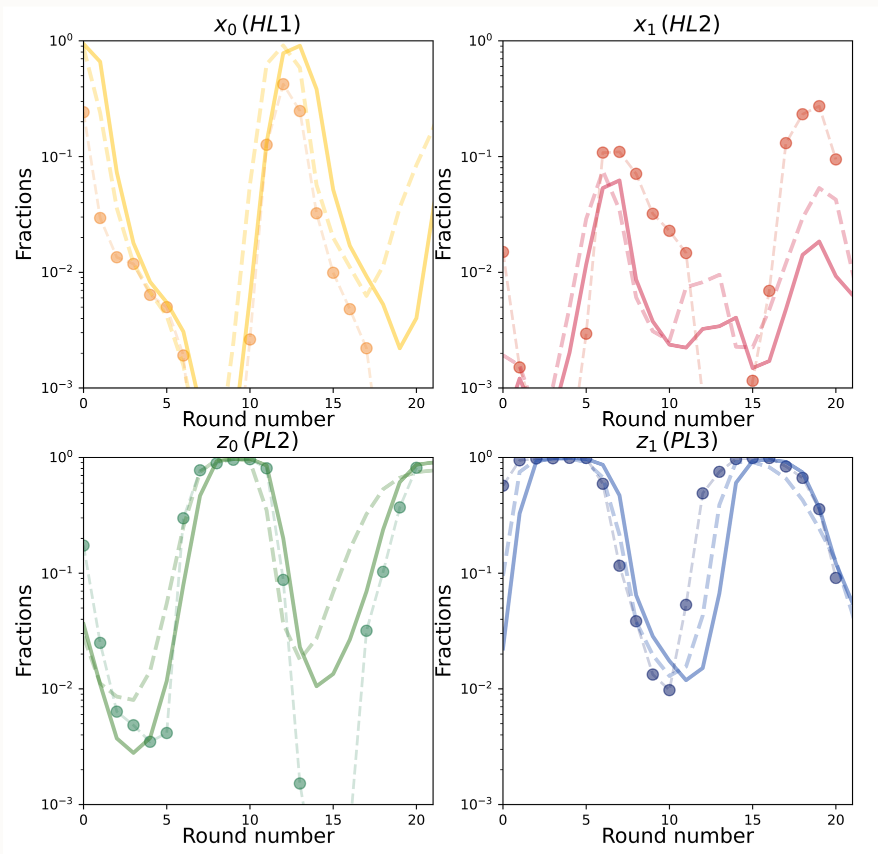
Those trends are validated **experimentally**.



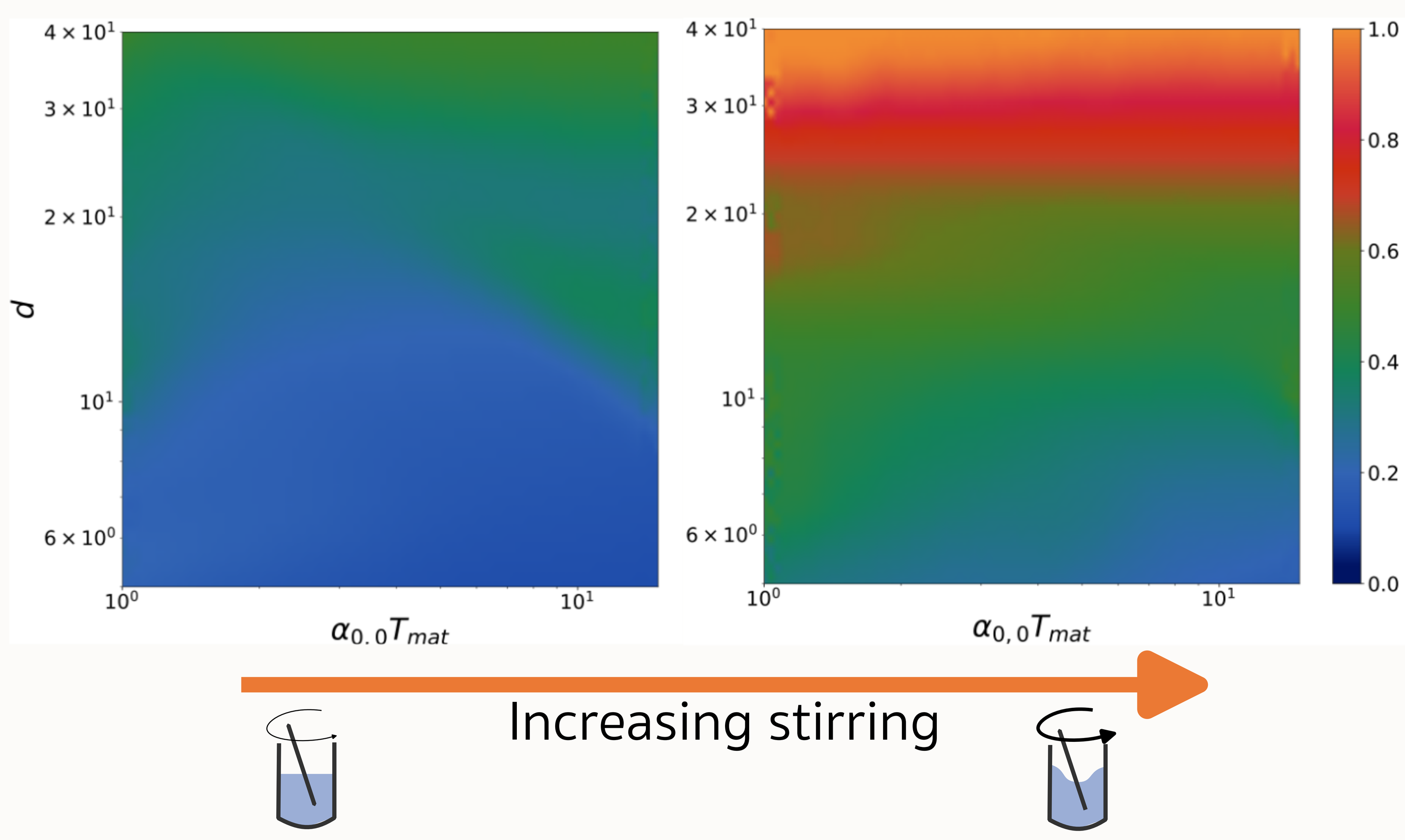
Finite size can lead to **extinction.**

Oscillatory dynamics

We observe **oscillations** between the different species (**theory and experiments**).



Effects of stirring, dilution and maturation



Dilution favors replicases by isolating parasites.

Maturation time mostly affects **mutations** but does not modify the total fraction of replicases if it's longer than the **typical replication time.**

[1]R Mizuuchi, T Furubayashi, N Ichihashi, Evolutionary transition from a single RNA replicator to a multiple replicator network. Nat. Commun. 13, 1460 (2022)

[2]A Blokhuis, D Lacoste, P Nghe, L Peliti, *Selection Dynamics in Transient Compartmentalization.* Phys. Rev. Lett. 120, 158101 (2018) Publisher: American Physical Society

[3]A Blokhuis, P Nghe, L Peliti, D Lacoste, *The generality of transient compartmentalization and its associated error thresholds.* J. Theor. Biol. 487, 110110 (2020)

[4]M Wu, PG Higgs, *Compositional Inheritance: Comparison of Self-assembly and Catalysis.* Orig. Life Evol. Biospheres 38, 399–418 (2008).