SIMPLICIALLY DRIVEN SIMPLE CONTAGION

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- 🦠 - 😷 unsafe behaviors boost pathogen spread

Interacting contagion models

- Simple contagions
- Contagions symmetrically coupled

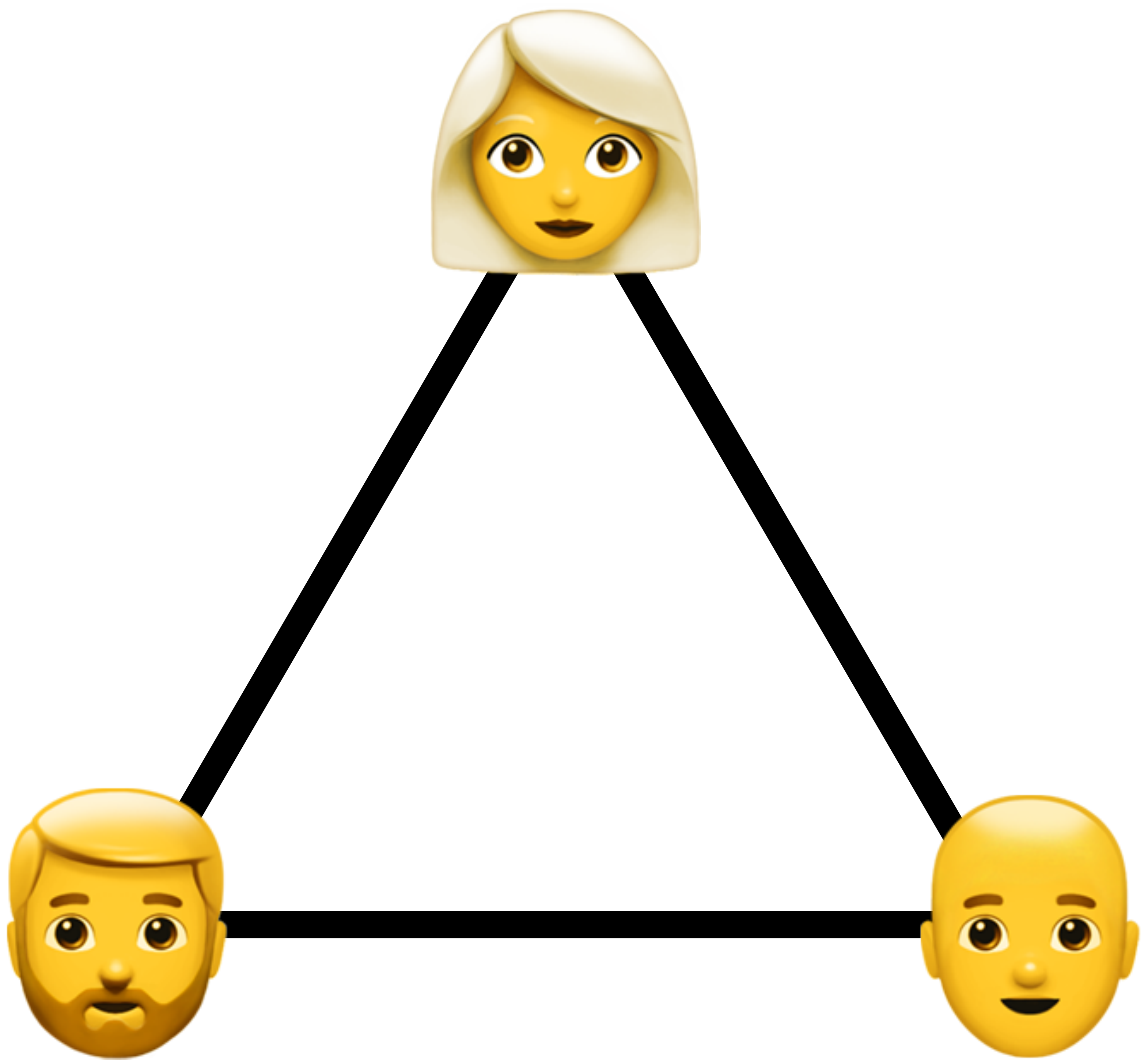
$$A \rightleftarrows B$$

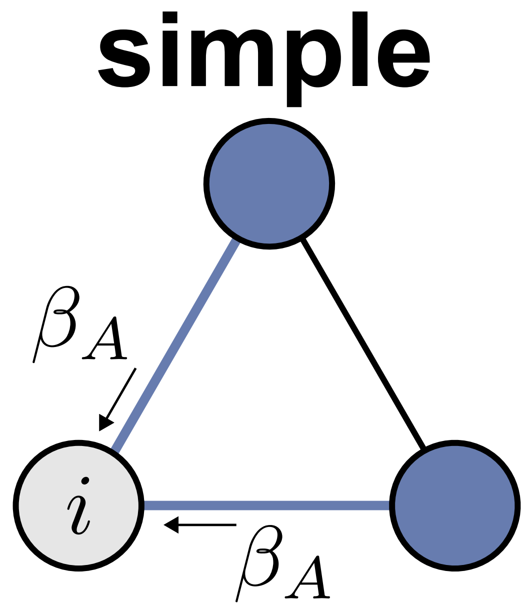
Social behaviors are better described by **complex contagions**, and interactions are often **not symmetric**. We do:

$$A \xrightarrow{\epsilon_{AB}} B \text{ and } B \xrightarrow{\epsilon_{BA}} A$$

e.g. W. Cai et al., Nat. Phys. 11, 936 (2015). L. Chen, et al., New J. Phys. 19, 103041 (2017).

Our spreading model





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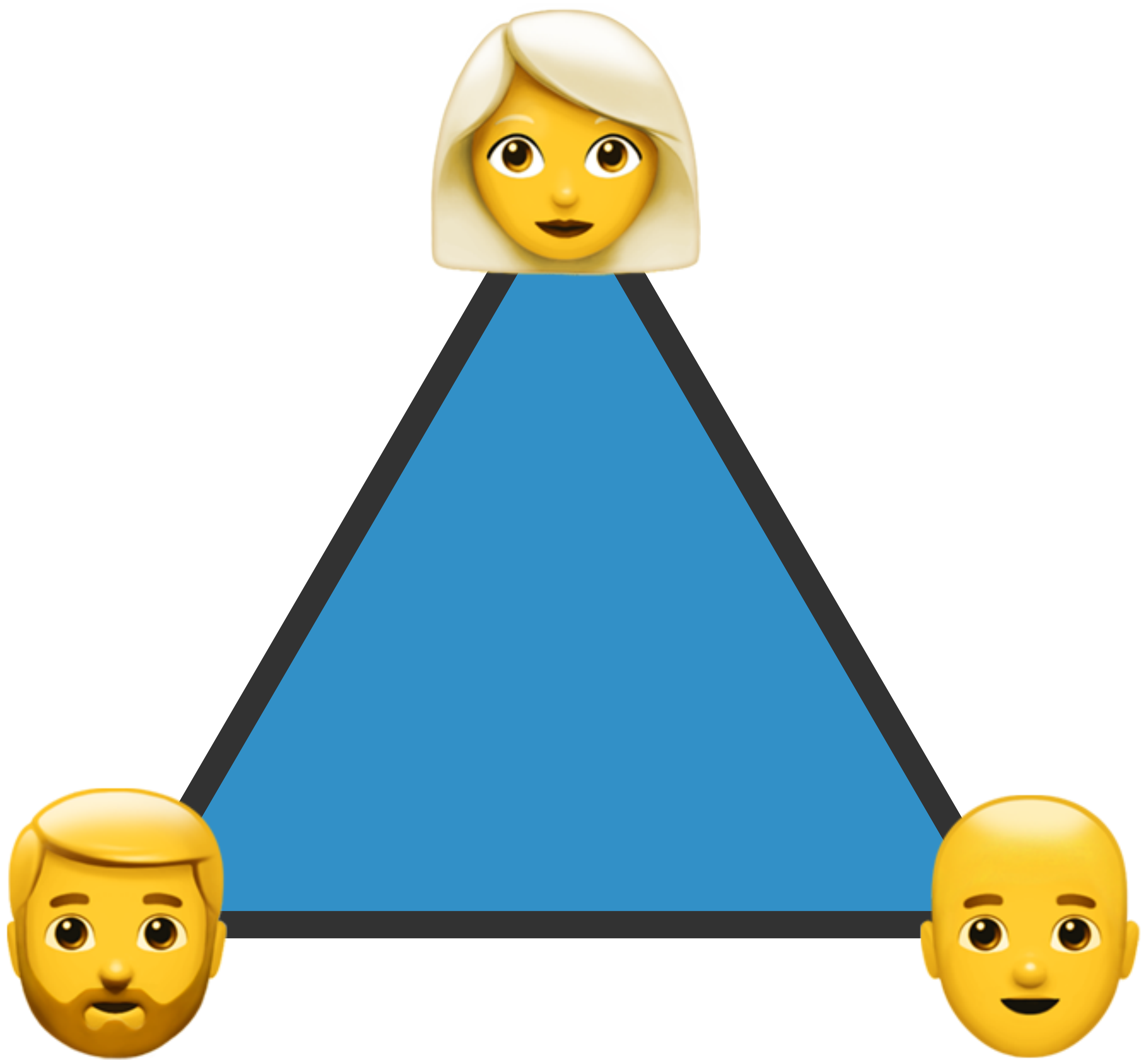

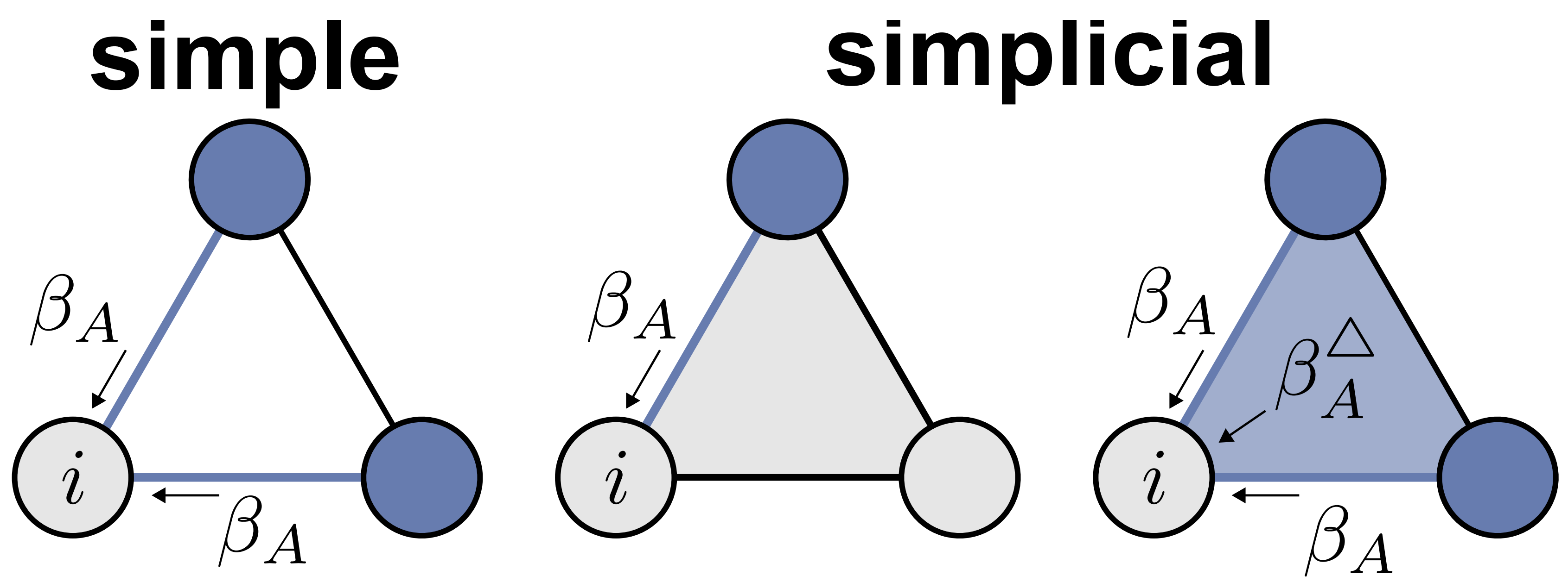

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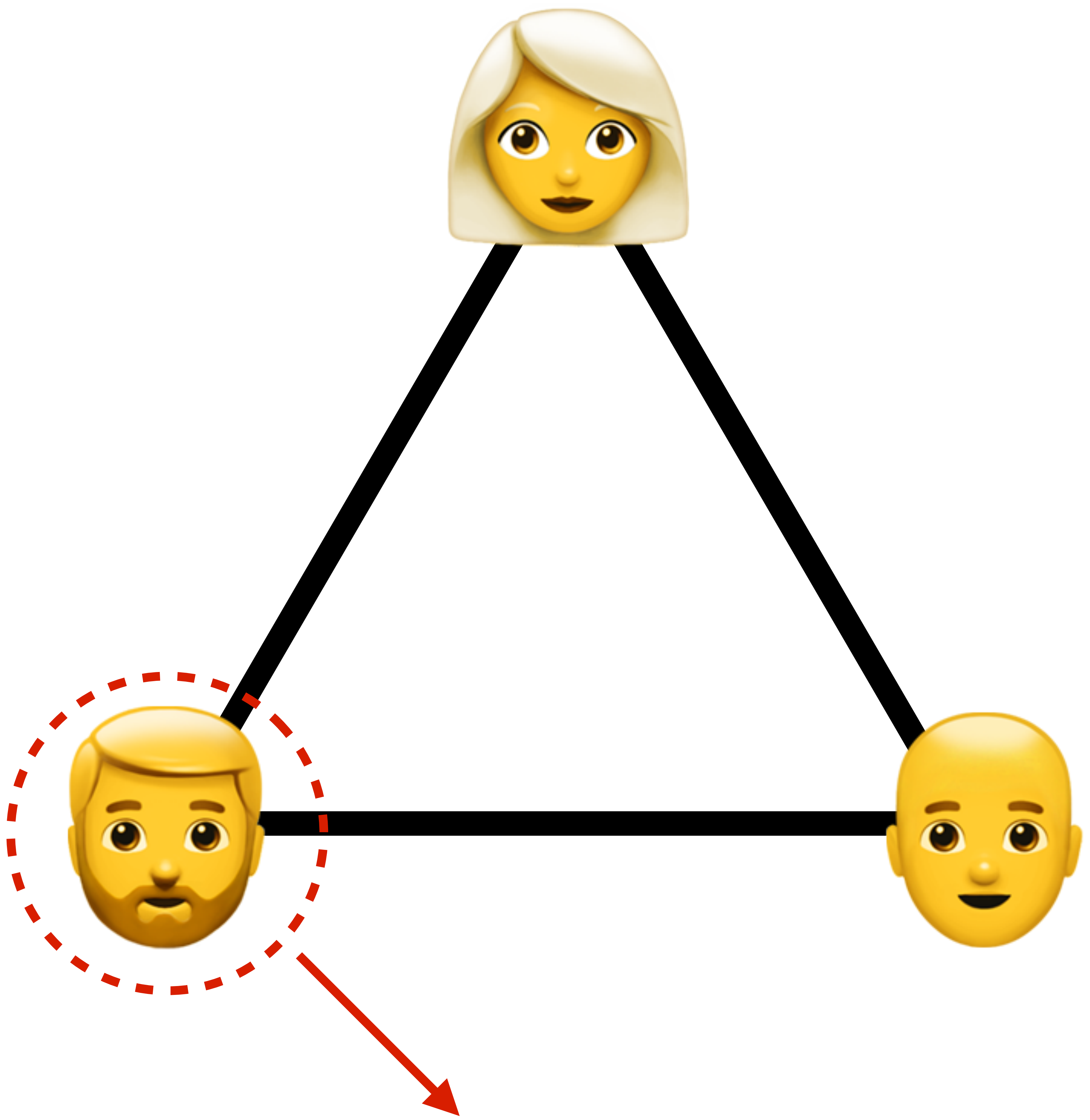

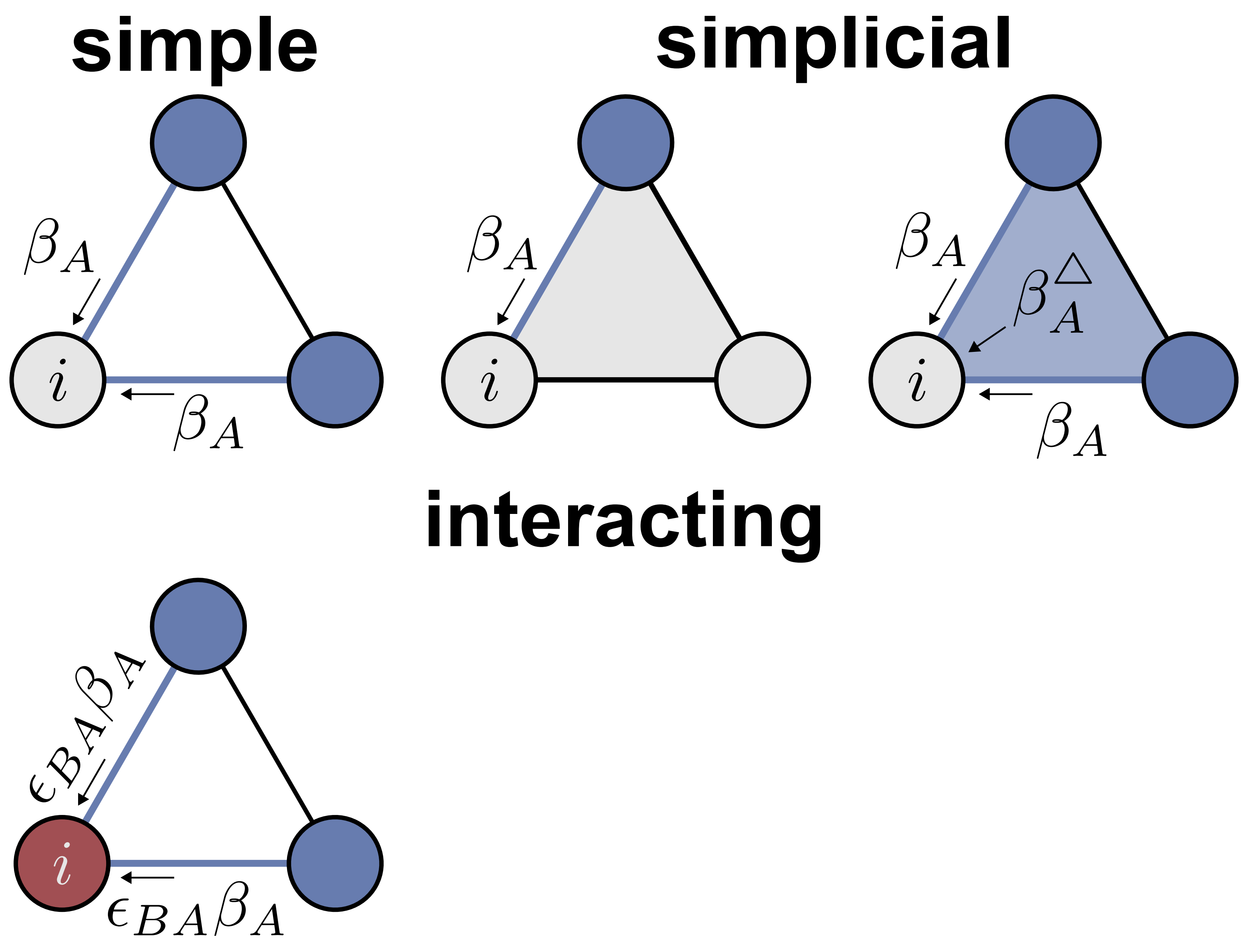

Infected with the other process

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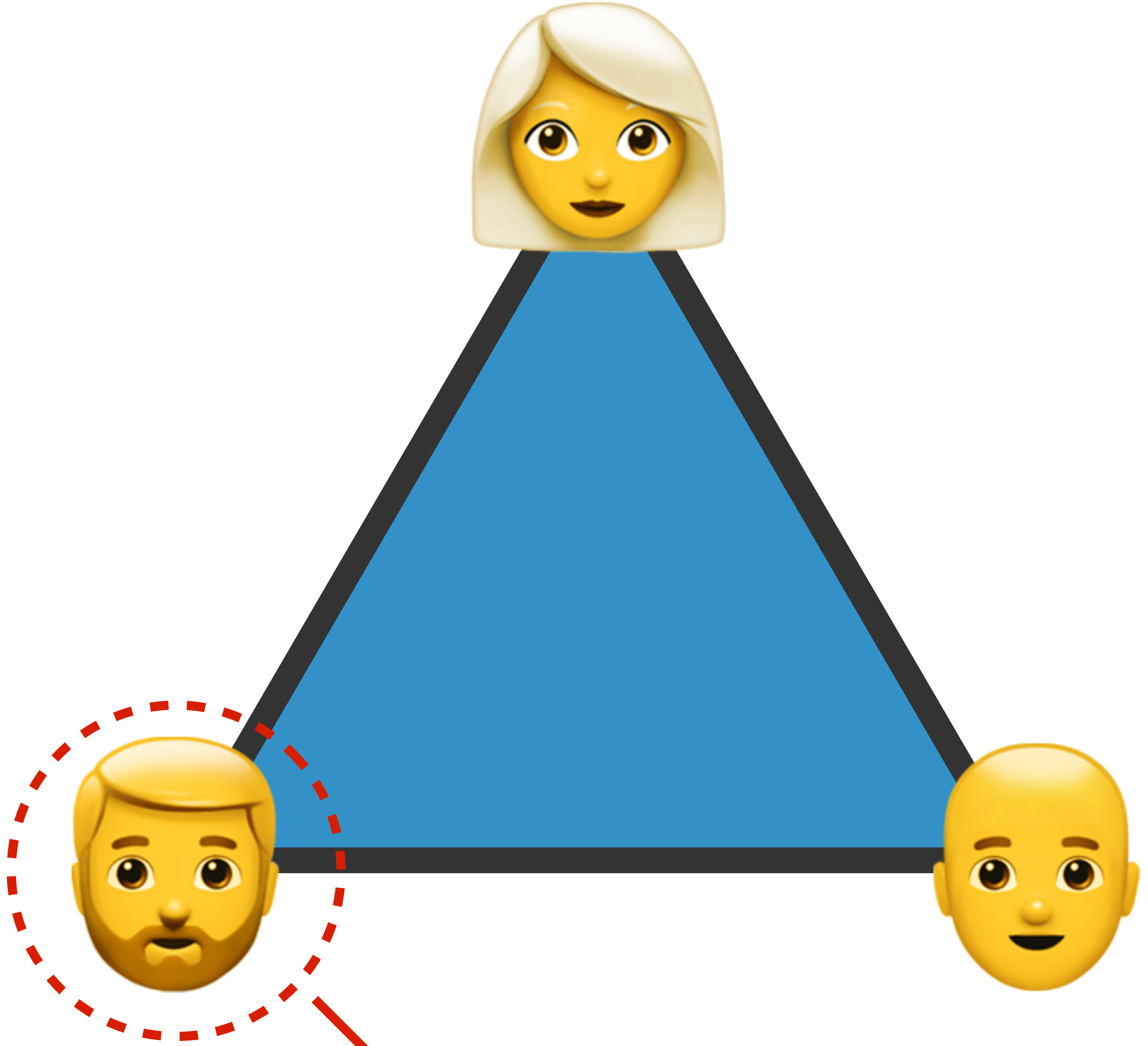

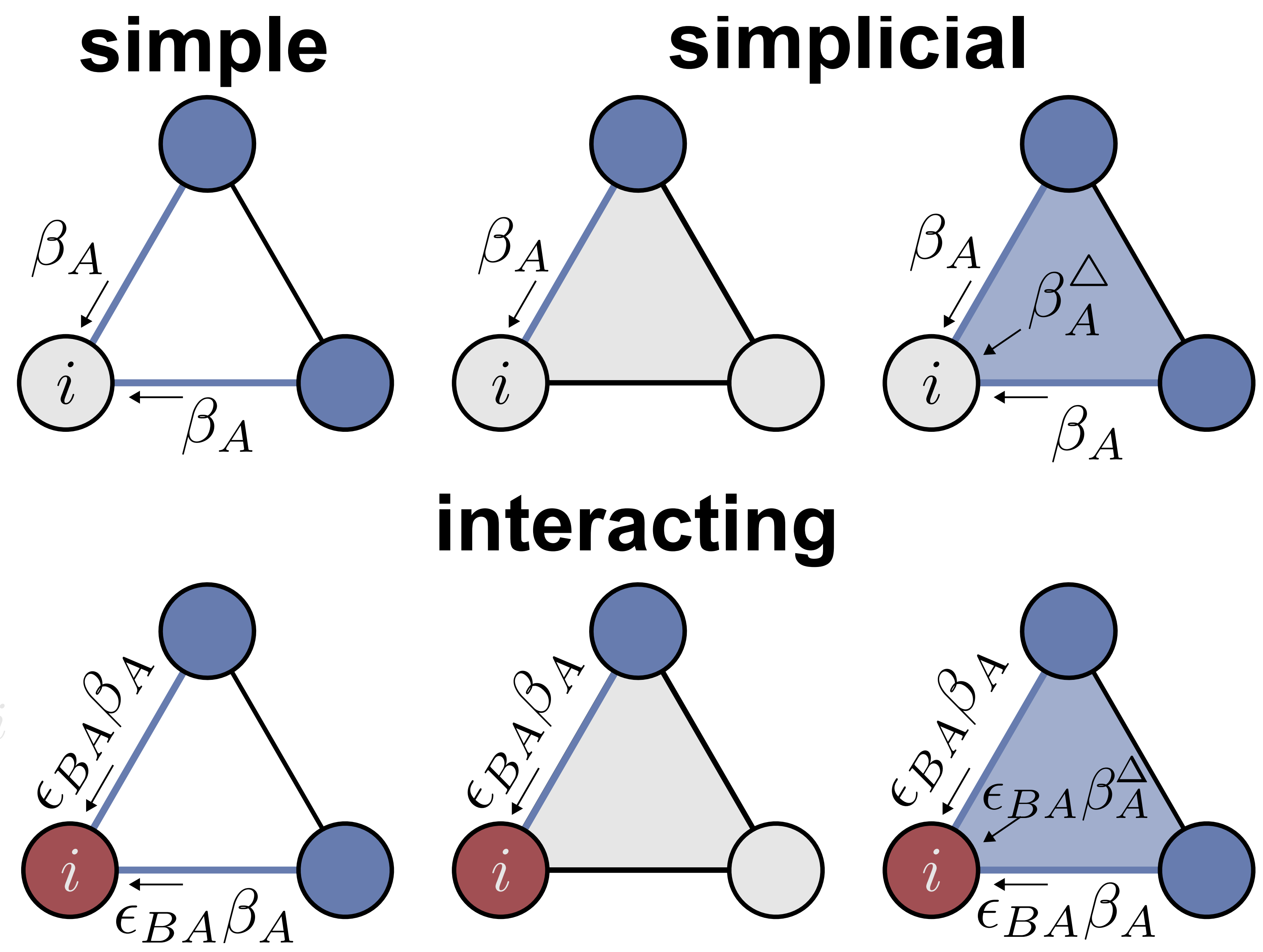

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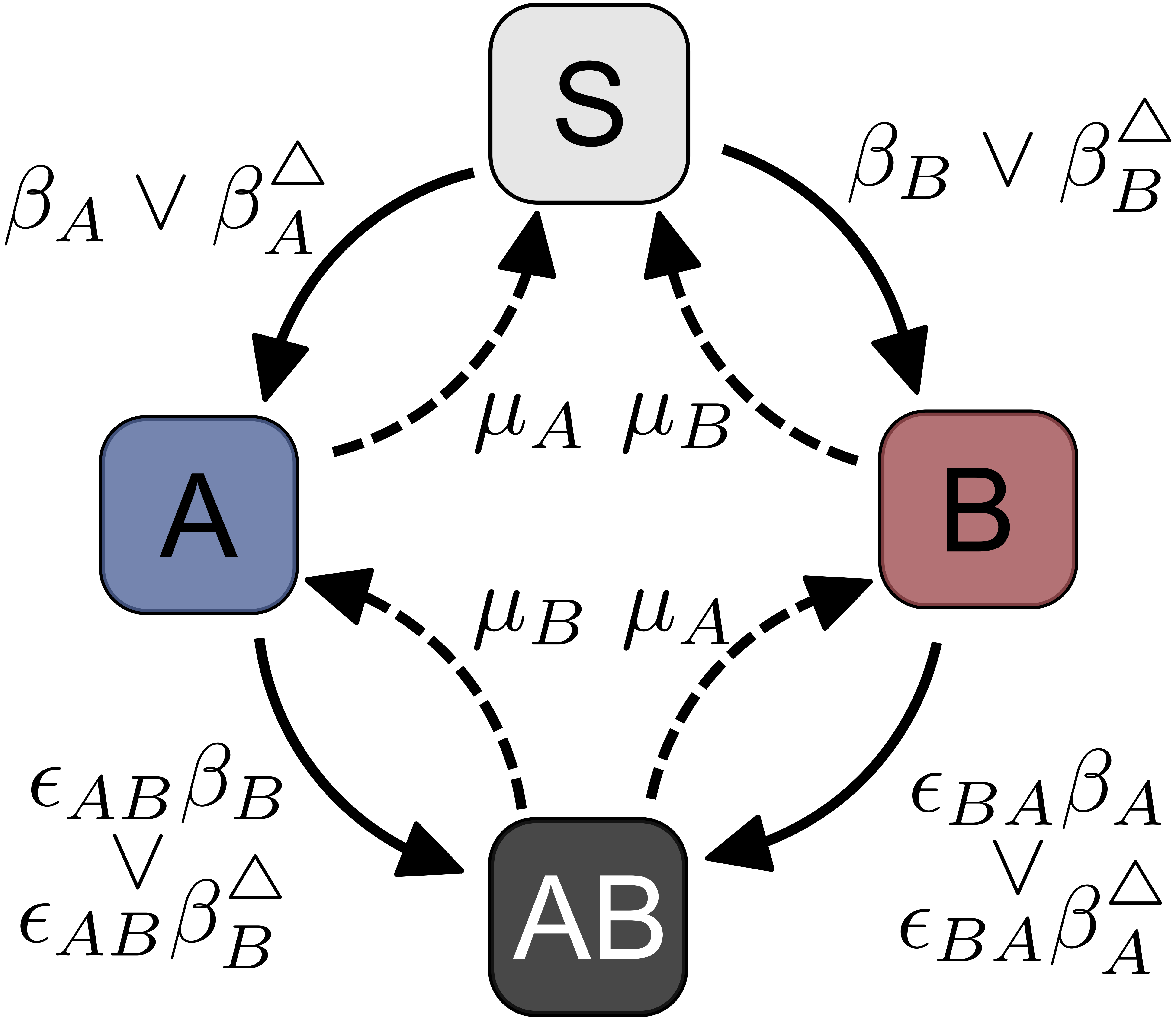

A (unsafe behavior)

drives

B (disease)

$\epsilon_{AB} > 1$ and $\epsilon_{BA} = 1$

Mean-field description

Setting $\mu_A = \mu_B = \mu$ and $\lambda_x = \beta_x \langle k \rangle / \mu$ and $\lambda_x^{\triangle} = \beta_x^{\triangle} \left\langle k_{\triangle} \right\rangle / \mu$ for $x \in \{A, B\}$

Mean-field description

$$\dot{\rho}_{A_{\text{tot}}} = \rho_{A_{\text{tot}}}\left[-1 + \lambda_A\left(1 - \rho_{A_{\text{tot}}}\right) + \lambda_A^{\triangle}\rho_{A_{\text{tot}}}(1 - \rho_{A_{\text{tot}}})\right]$$

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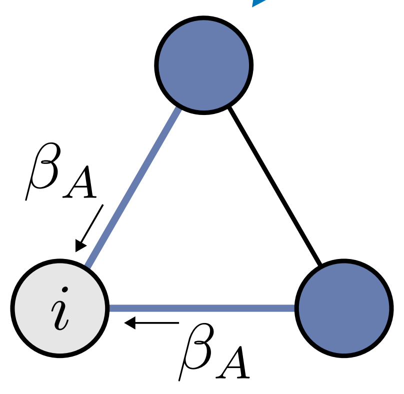

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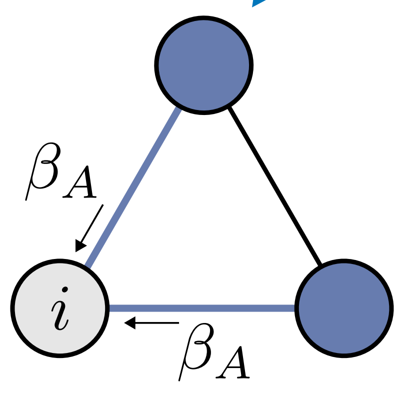

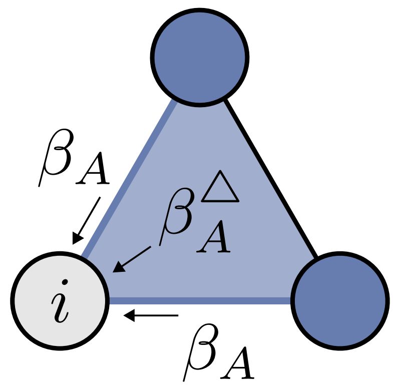

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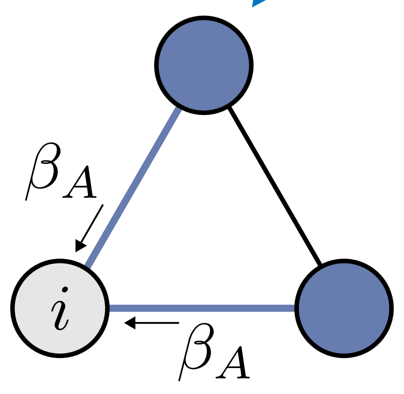

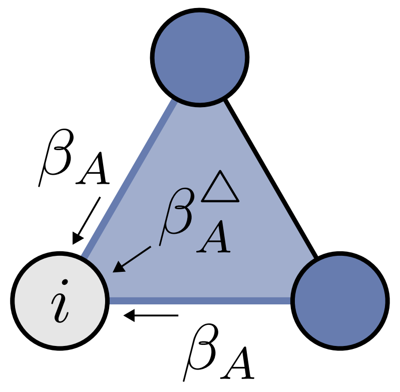

$$\dot{\rho}_{B_{\text{tot}}} = \rho_{B_{\text{tot}}} \left[-1 + \lambda_B \left(1 - \rho_{B_{\text{tot}}} \right) + \lambda_B (\epsilon_{AB} - 1)(\rho_{A_{\text{tot}}} - \rho_{AB}) \right]$$

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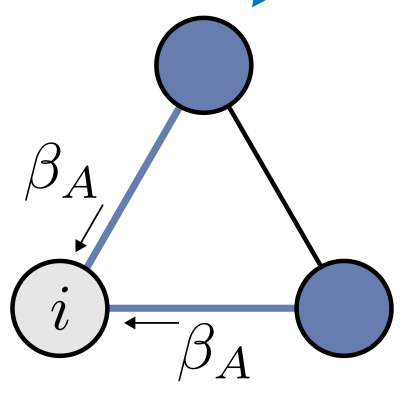

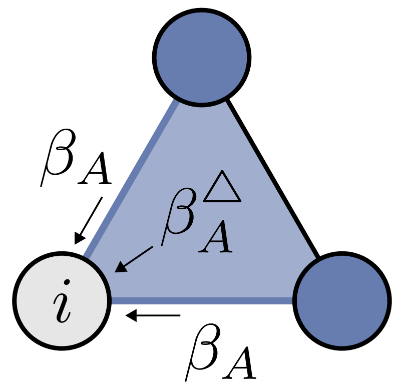

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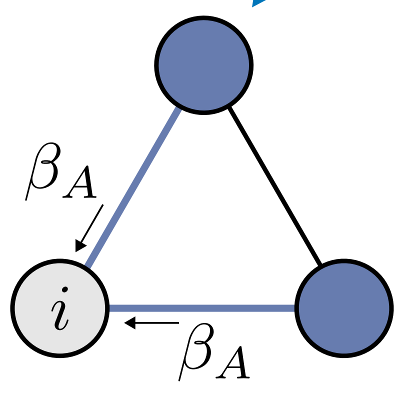

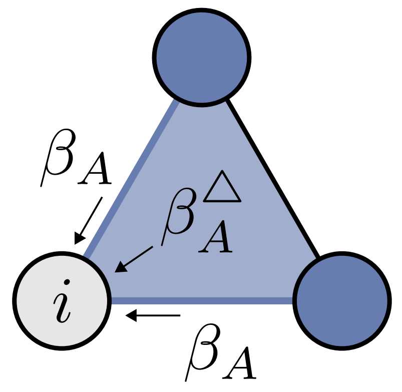

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$$\dot{\rho}_{AB} = -2\rho_{AB} + \epsilon_{AB}\lambda_B(\rho_{A_{\text{tot}}} - \rho_{AB})\rho_{B_{\text{tot}}} + \lambda_A(\rho_{B_{\text{tot}}} - \rho_{AB})\rho_{A_{\text{tot}}} +$$

$$+ \lambda_A^{\triangle}(\rho_{B_{\text{tot}}} - \rho_{AB})\rho^2_{A_{\text{tot}}}$$

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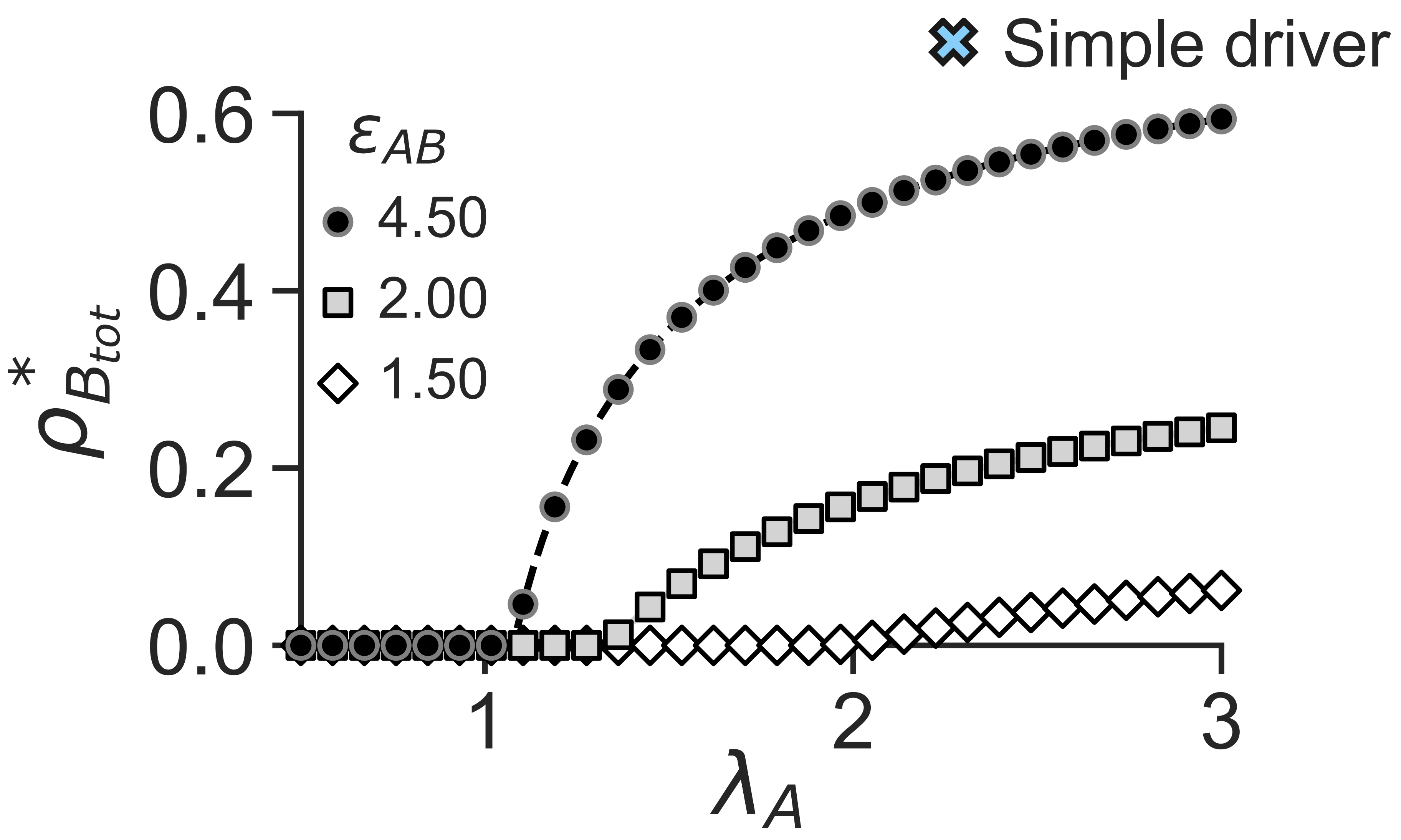

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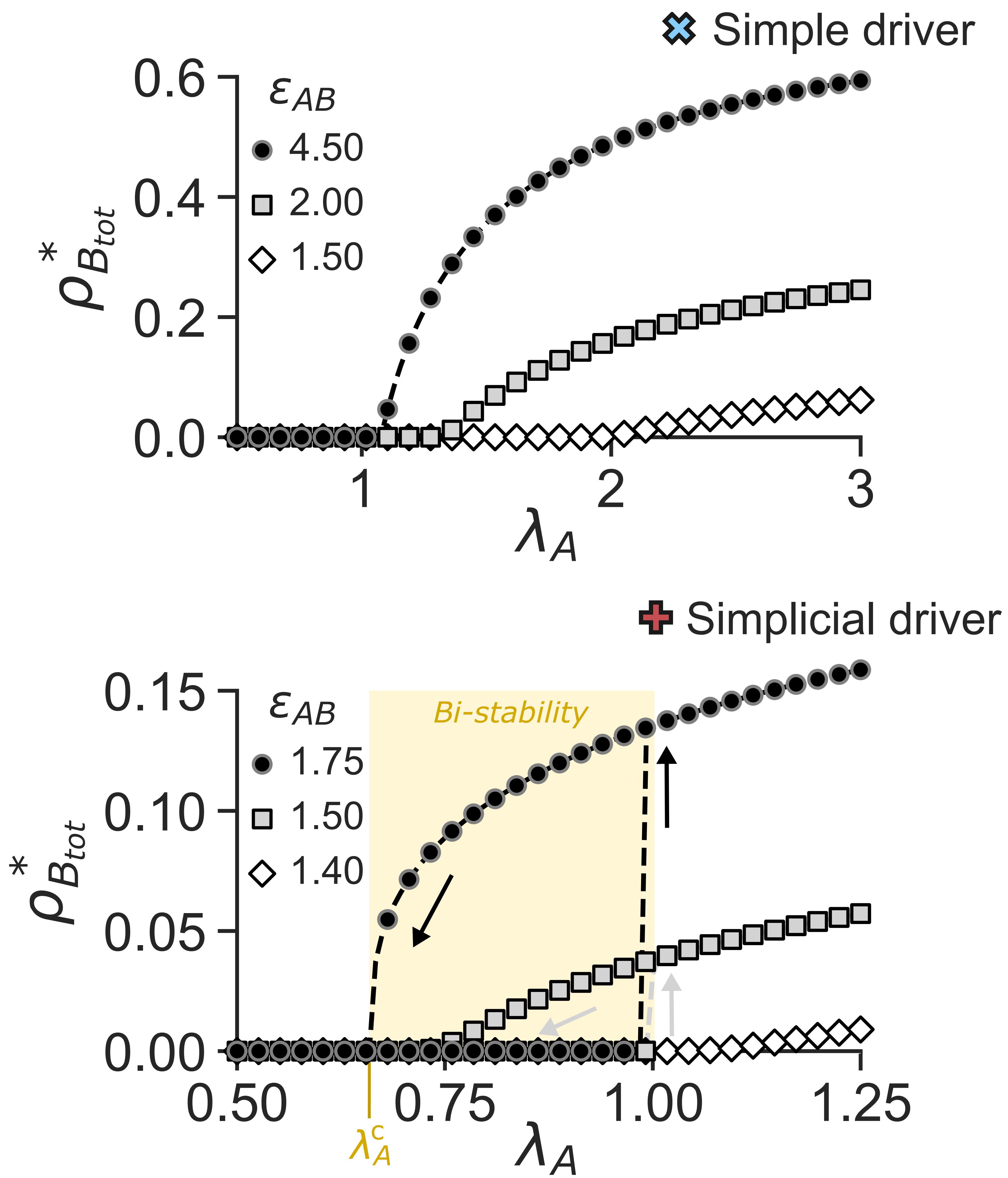

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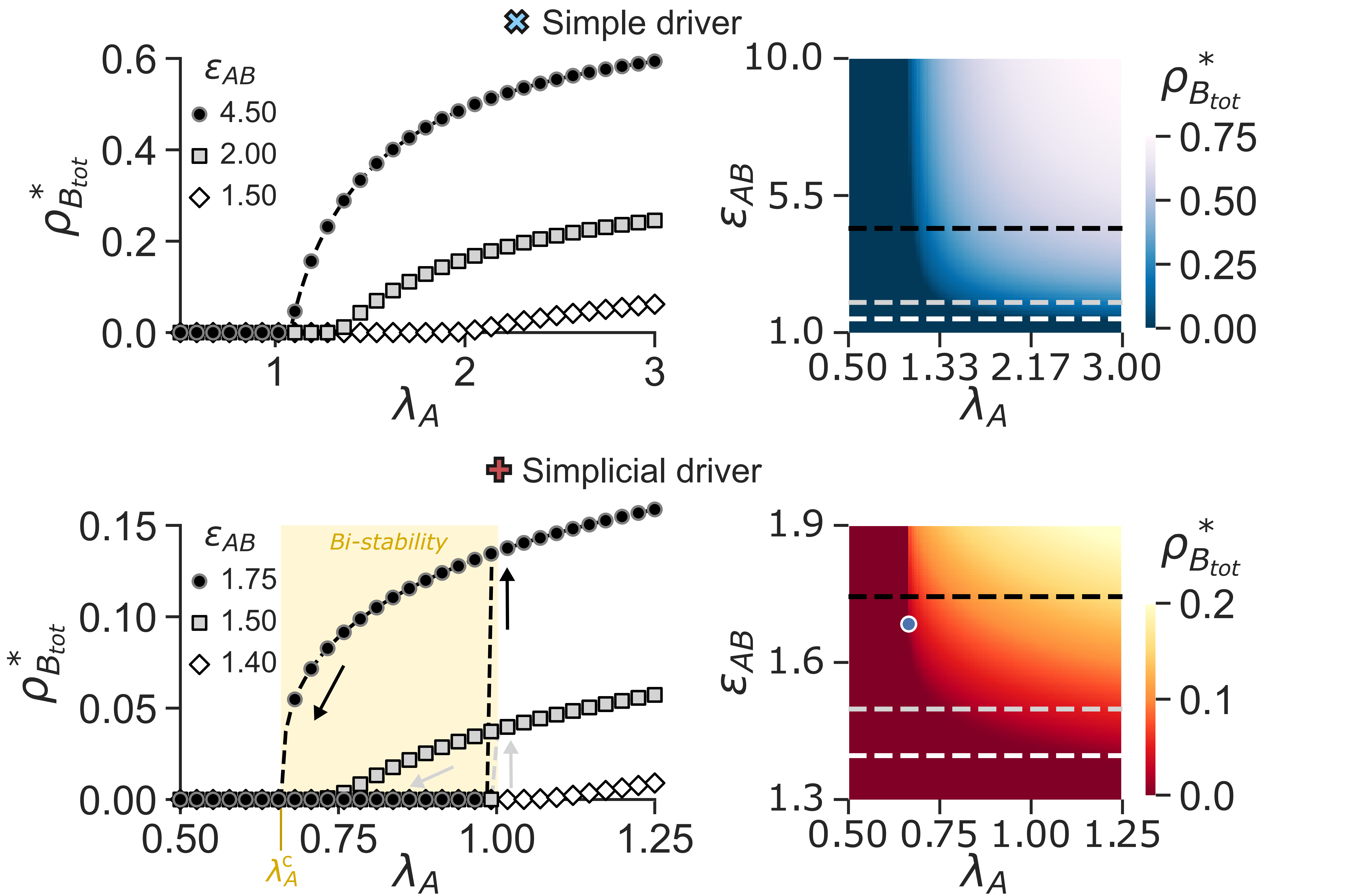

Results

Critical driving strength

$$\epsilon_{AB}^{c} = \begin{cases} \dfrac{\sqrt{\lambda_A^{\triangle}} - \lambda_B}{\left(\sqrt{\lambda_A^{\triangle}} - 1\right)\lambda_B} & \text{in reg. I} \\ 1 & \text{in reg. II} \end{cases}$$

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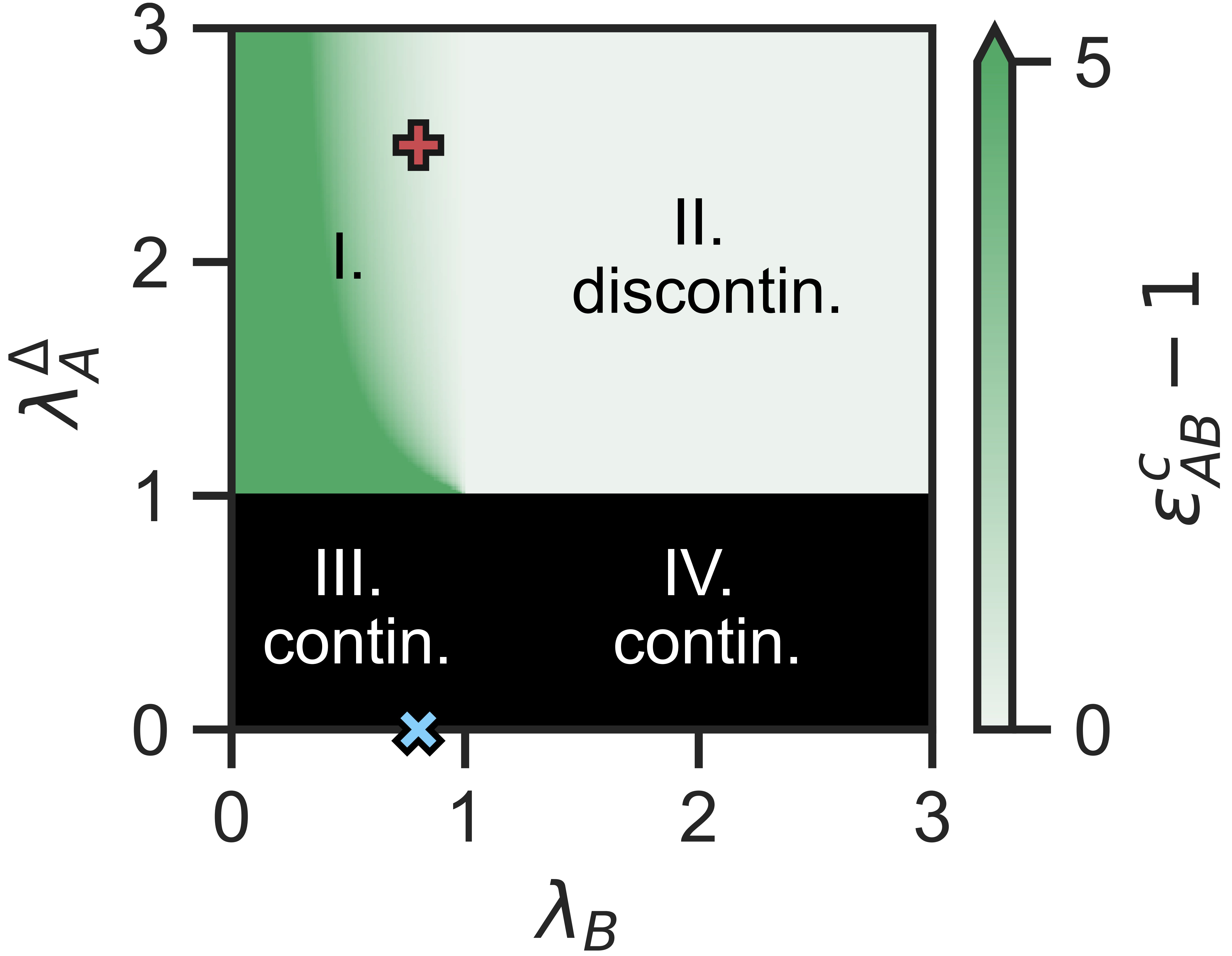
If $\epsilon_{AB} \geq \epsilon_{AB}^{c}$: 💥

Results

Full phase diagram



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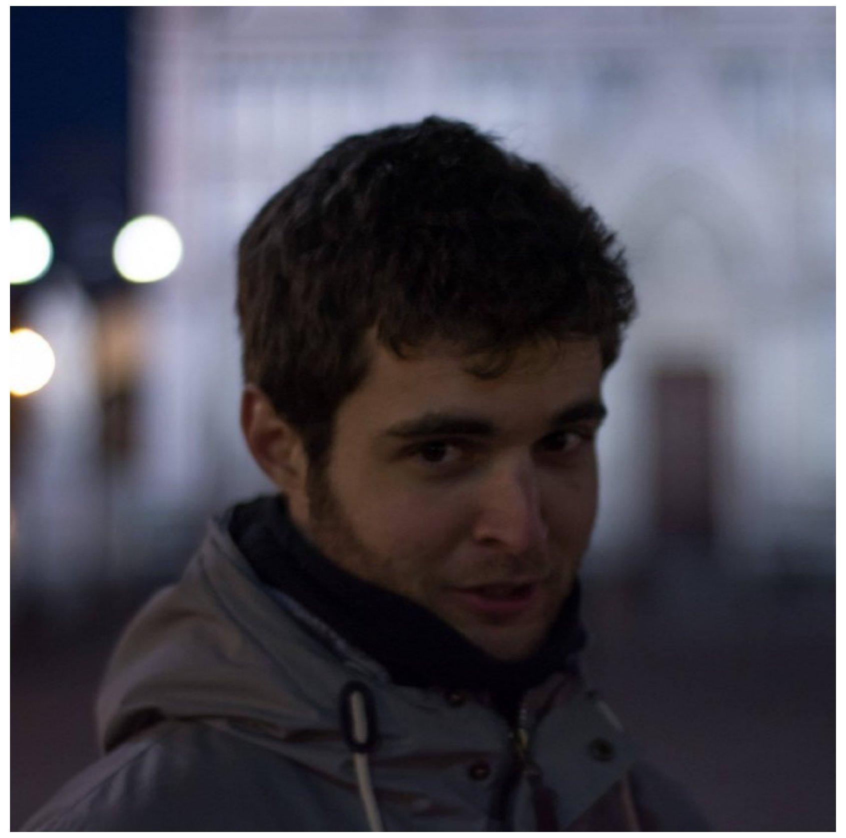
Food for thought

- **Need for disease models integrating behavioral components (e.g. compliance/non-compliance)**
- **Need for a better understanding of behavioral/ social processes**

Maxime Lucas



Iacopo Iacopini

Alain Barrat

Giovanni Petri

QUESTIONS?

Full paper:

Lucas, M., Iacopini, I., Robiglio, T., Barrat, A., & Petri, G. (2023). **Simplicially driven simple contagion**. *Physical Review Research*, *5*(1), 013201.

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