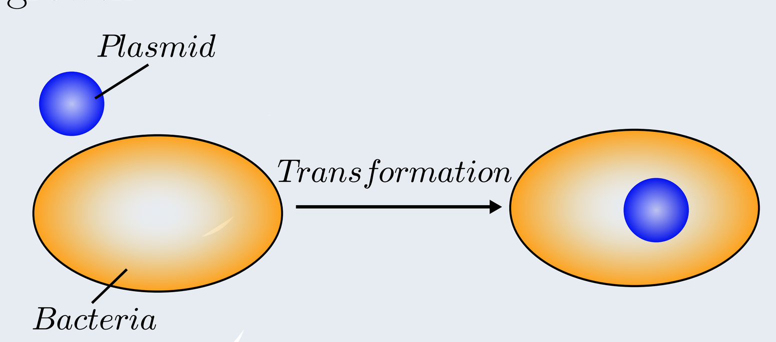
Simulation and Theory of Bacterial Transformation

JD Russo, Jiajia Dong

Department of Physics and Astronomy, Bucknell University

Introduction

- Ubiquitous threat of antibiotic resistant bacteria
- Investigate effect of different cellular transformation rates on antibiotic resistant bacterial population growth



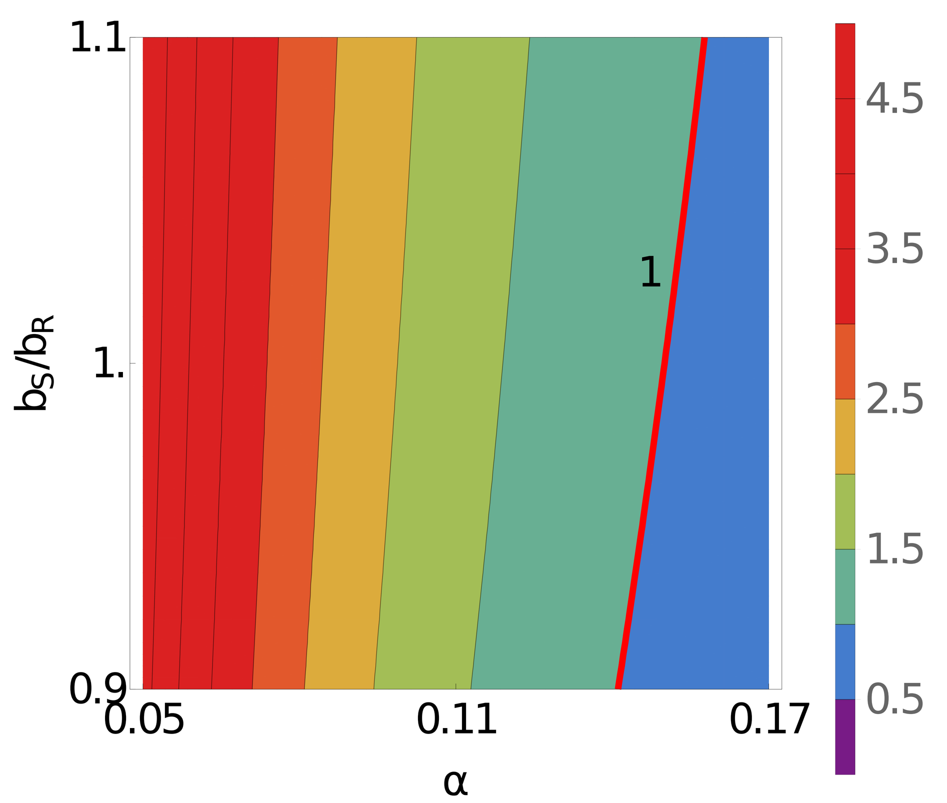
Biological Background

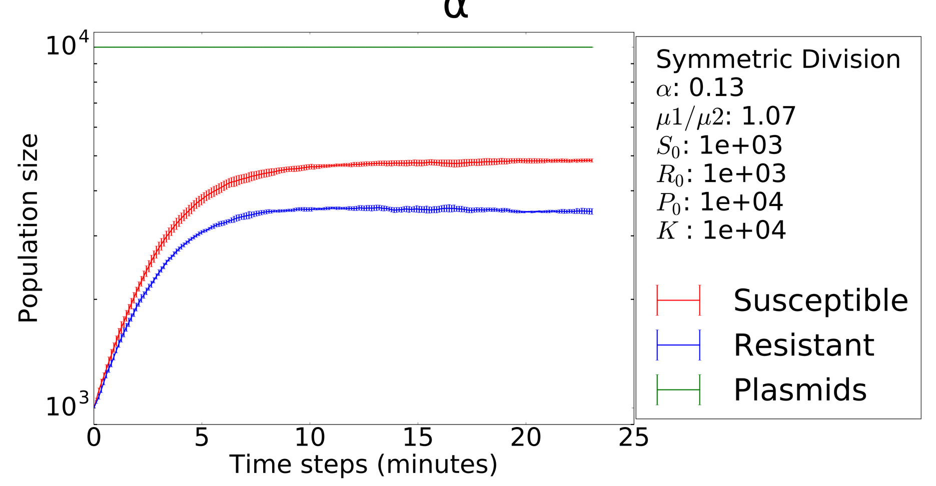
- Plasmids
- Fitness cost
- Transformation

Simulation Methods

- Combined approach of Kinetic Monte Carlo simulation and numerical modeling
- Gillespie algorithm
- Well-mixed population
- Carrying capacity
- Constant, Linear, Recycled α
- Symmetric division

Constant α





Reactions

$S \xrightarrow{b_S} 2S$

$S \xrightarrow{\alpha} R$

$R \xrightarrow{b_R} 2R$

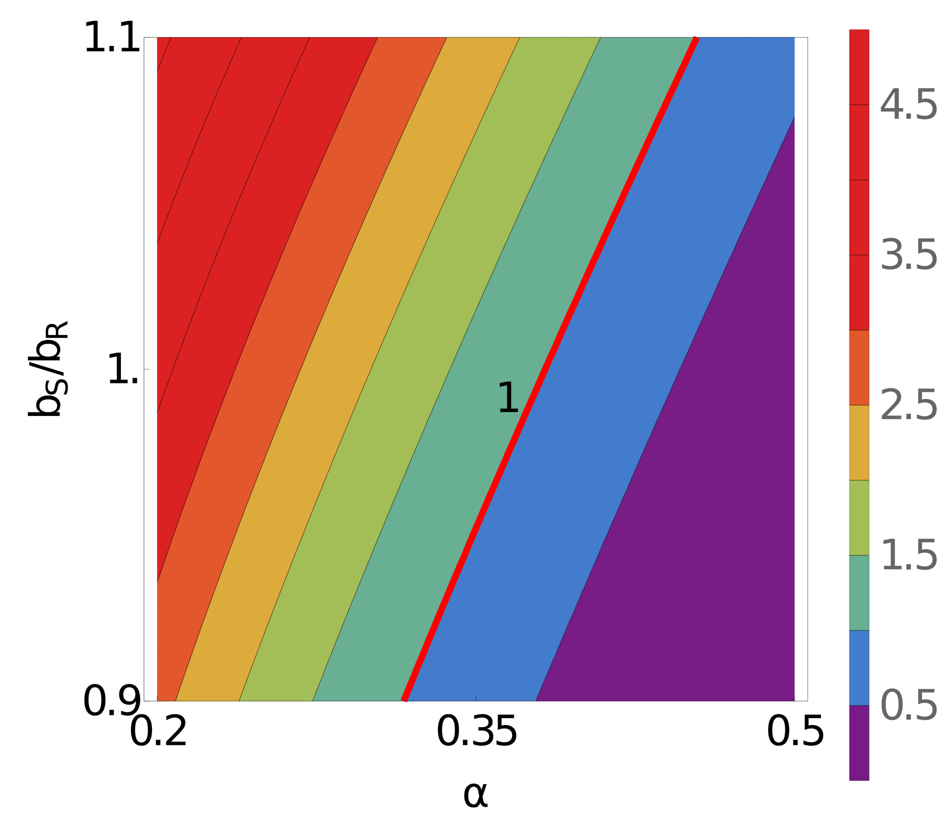
$R \xrightarrow{\delta} \varnothing$

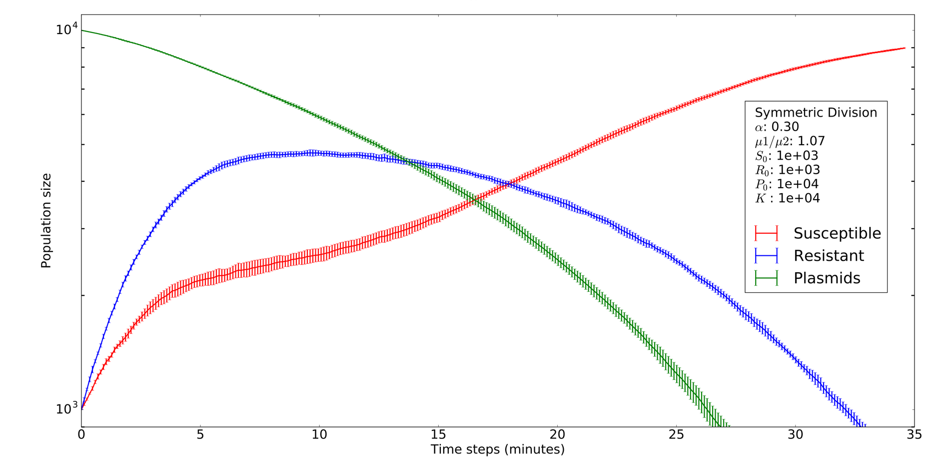
Equations

$$\frac{dS}{dt} = b_S\left(1 - \frac{S+R}{K}\right) S - \alpha S$$

$$\frac{dR}{dt} = b_R\left(1 - \frac{S+R}{K}\right) R + \alpha S - \delta R$$

Linear α





Reactions

$S \xrightarrow{b_S} 2S$

$S + P \xrightarrow{\alpha} R$

$R \xrightarrow{b_R} 2R$

$R \xrightarrow{\delta} \varnothing$

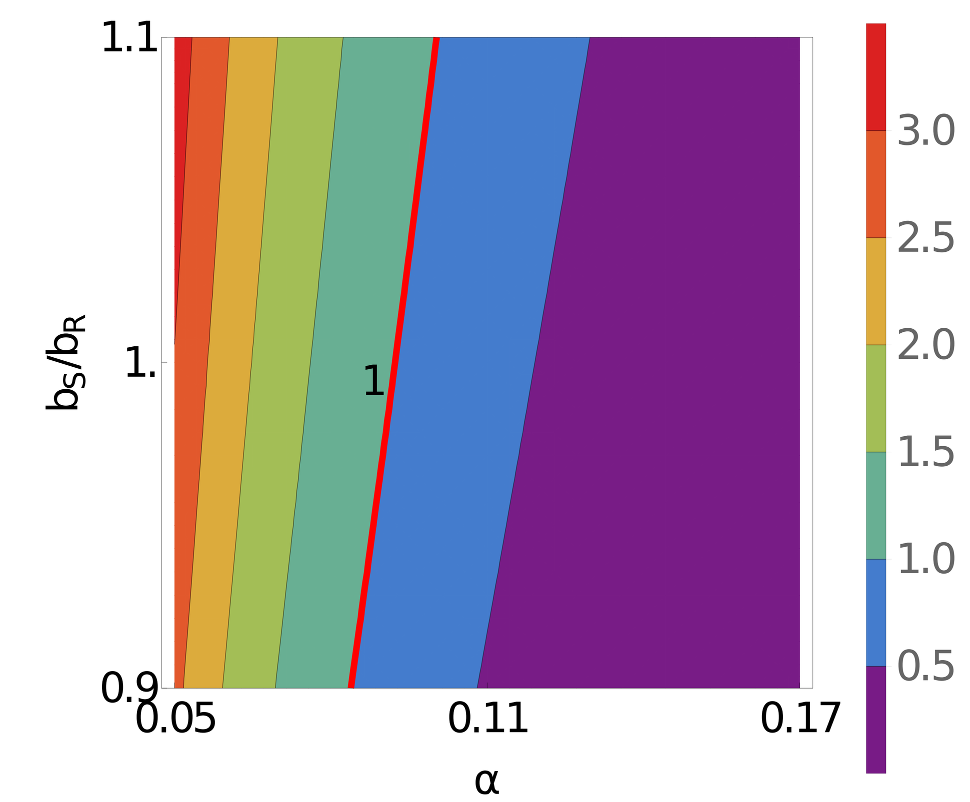
Equations

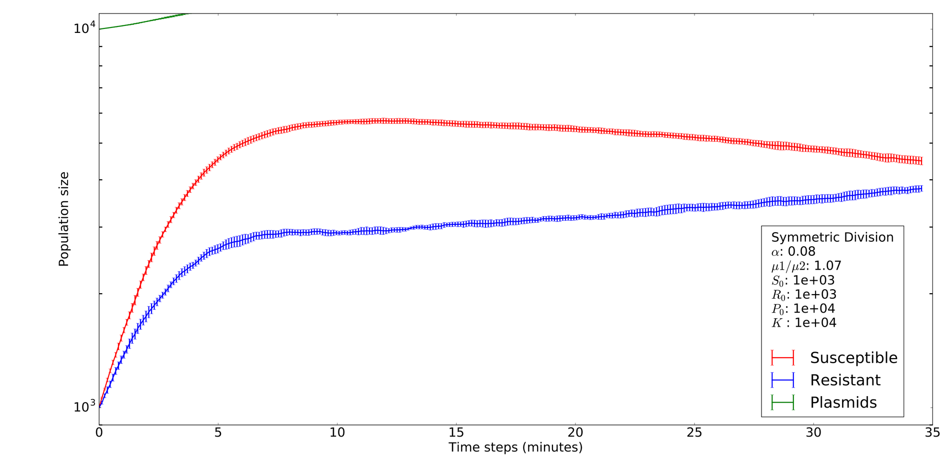
$$\frac{dS}{dt} = b_S\left(1 - \frac{S+R}{K}\right) S - \alpha\left(\frac{P}{P_0}\right) S$$

$$\frac{dR}{dt} = b_R\left(1 - \frac{S+R}{K}\right) R + \alpha\left(\frac{P}{P_0}\right) S - \delta R$$

$$\frac{dP}{dt} = -\alpha\left(\frac{P}{P_0}\right) S$$

Recycled α





Reactions

$S \xrightarrow{b_S} 2S$

$S + P \rightarrow R$

$R \rightarrow 2R$

$R \rightarrow \varnothing + P$

Equations

$$\frac{dS}{dt} = b_S\left(1 - \frac{S+R}{K}\right) S - \alpha\left(\frac{P}{P_0}\right) S + +b_R\left(1 - \frac{S+R}{K}\right) R$$

$$\frac{dR}{dt} = \alpha\left(\frac{P}{P_0}\right) S - \delta R$$

$$\frac{dP}{dt} = -\alpha\left(\frac{P}{P_0}\right) S + \delta R$$

Conclusions

- S/R transition point depends on both rate and mechanism
- Population extinction in linear case

Future Work

- Simulation on a lattice
- Adding antibiotics
- Asymmetric division

Acknowledgements/References

Thank you etc etc

- Source 1
- Source 2