

# How Quorum Sensing Interactions Affect Population Structure

02-712 Final Project

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Wenger

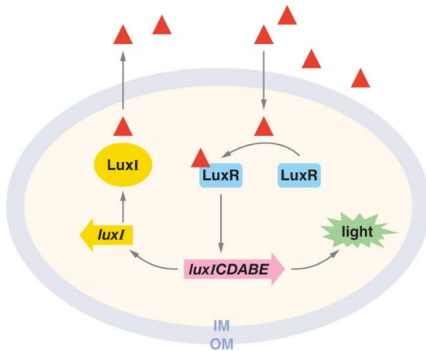
Carnegie Mellon University

December 2, 2021

# Background



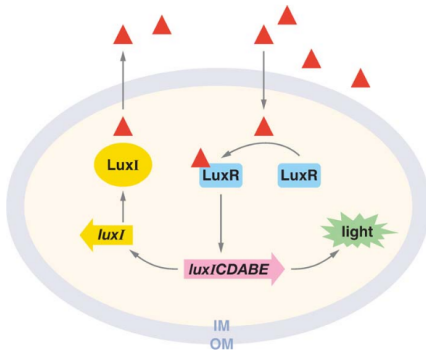
# Quorum-Sensing Systems



- ▶ Signal-Receptor molecule pairs that modulate gene expression
- ▶ Once threshold density is reached, enough signal is received to upregulate target genes

Figure 1: Waters and Bassler (2005)

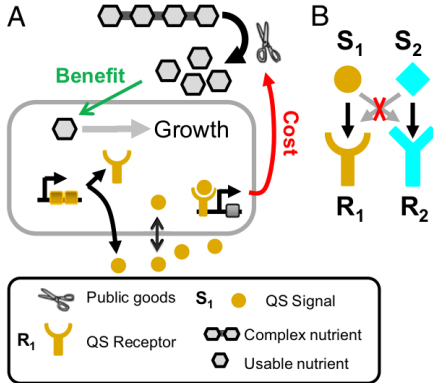
# Quorum-Sensing Systems



- ▶ Signal-Receptor molecule pairs that modulate gene expression
- ▶ Once threshold density is reached, enough signal is received to upregulate target genes
- ▶ Can lead to biofilms, antibiotic production etc.

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# Public Goods and Cheating



- ▶ When quorum is reached, bacteria produce a “public good”

Figure 2: Eldar (2011)

## Public Goods and Cheating

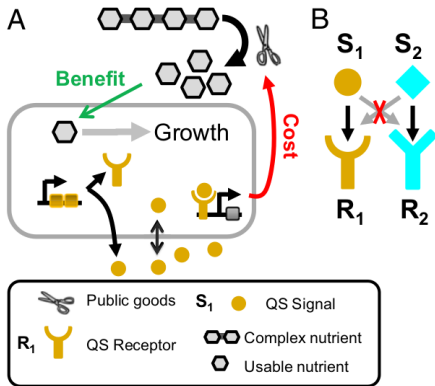


Figure 2: Eldar (2011)

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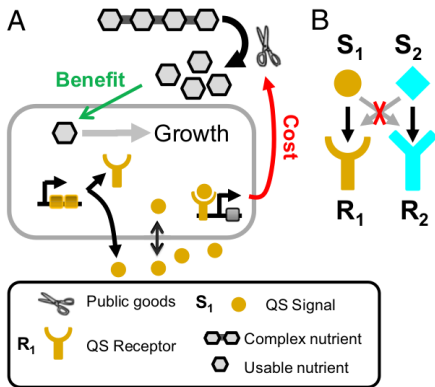


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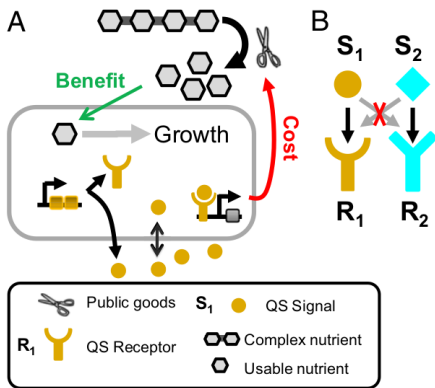


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- ▶ When quorum is reached, bacteria produce a “public good”
- ▶ Everyone benefits from this even if they don’t contribute
- ▶ Must produce the receptor, signal molecule and good to contribute
- ▶ Cheaters DO prosper (if you are a bacterium)

# Who Cares?

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  - ◇ interfere with microbiome colonization
  - ◇ interfere with biofilm formation and competitions

# Methods

# Basic ODE Model

## Social conflict drives the evolutionary divergence of quorum sensing

Avigdor Eldar<sup>1</sup>

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### Model Equations

$$\frac{dn_i}{dt} = n_i \left( \frac{P_d}{P_d + 1} (1 - rf(R_i^{\text{active}})) - n_{\text{tot}} - \gamma_n \right)$$

$$\frac{dS_i}{dt} = \beta_S (n_i - S_i)$$

$$\frac{dE}{dt} = -\beta_E E + \sum_i f(R_i^{\text{active}}) n_i$$

$$\frac{dP_d}{dt} = J_{P_d} + V_{\text{max}} E - \beta_{P_d} \left( \frac{P_d}{P_d + 1} \right) n_{\text{tot}}$$

## Signal-Receptor Activation Matrix $K_{ac}$

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- ▶  $K_{ac}$  is of dimension  $|R| \times |S| = |n| \times |n|$

## Facultative Cheaters

Matrix for 2 strains  $R_1S_1$  and  $R_2S_2$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

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## Custom Matrix

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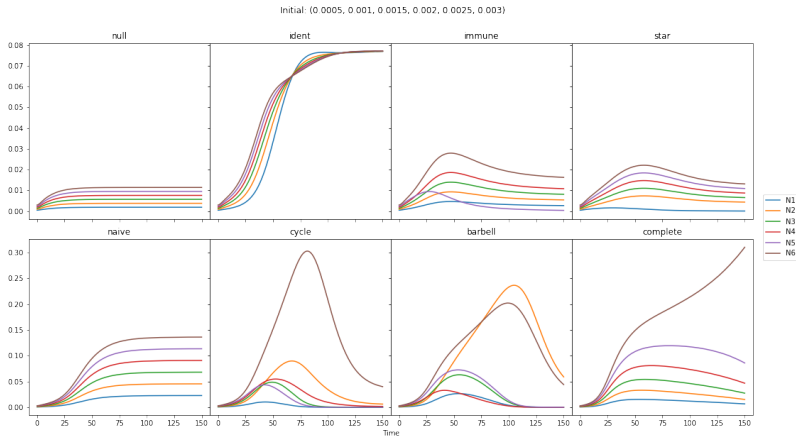
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- ▶ All code/results easily available to use on Github

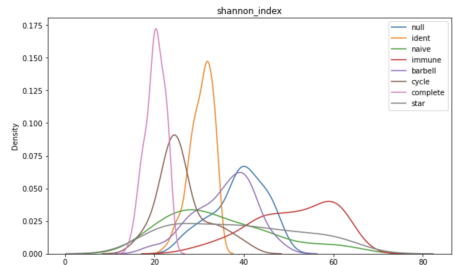
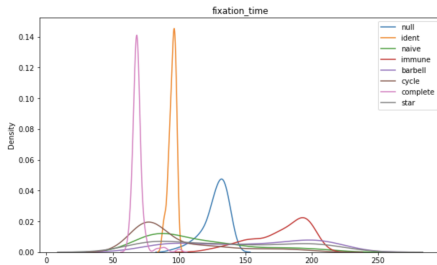
# Results

# Comparing Different $K_{ac}$ Matrices

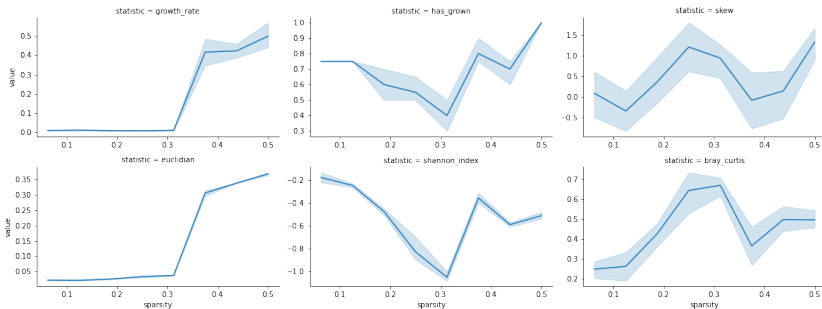




# How Different $K_{ac}$ affect model dynamics



# How $K_{ac}$ Sparsity Affects Population Structure



# Discussion

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  - ◇ modelling fish Tinder

# Moral of the Study

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Cheating works...

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(for bacteria)

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Cheating works...

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but cooperating is better!

# Bibliography I

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