How Quorum Sensing Interactions Affect Population Structure

02-712 Final Project

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Background

Quorum-Sensing Systems

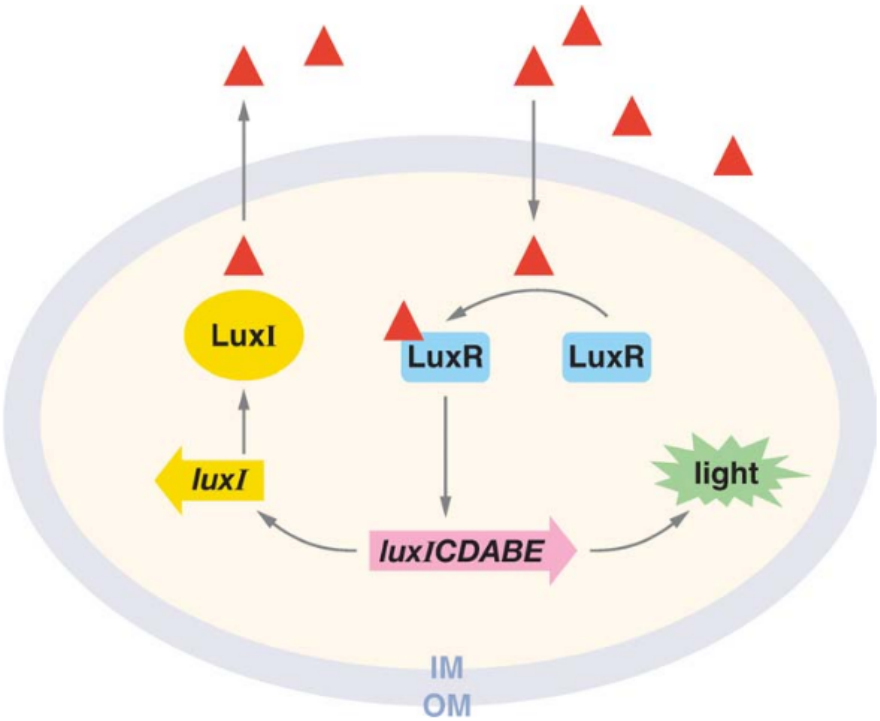
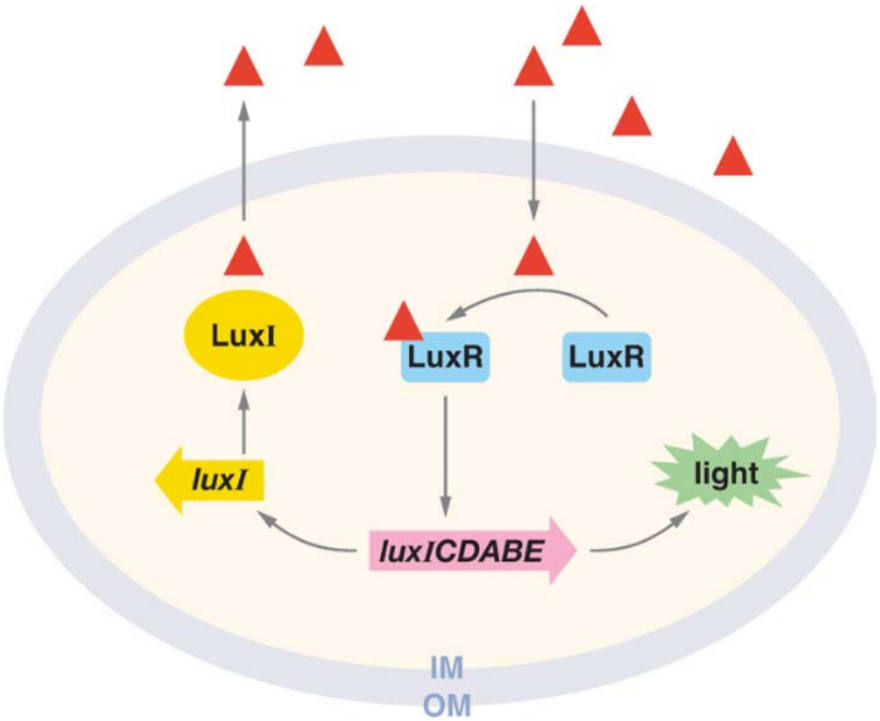


Figure 1: @qs_diagram

- Signal-Receptor molecule pairs that modulate gene expression

Quorum-Sensing Systems



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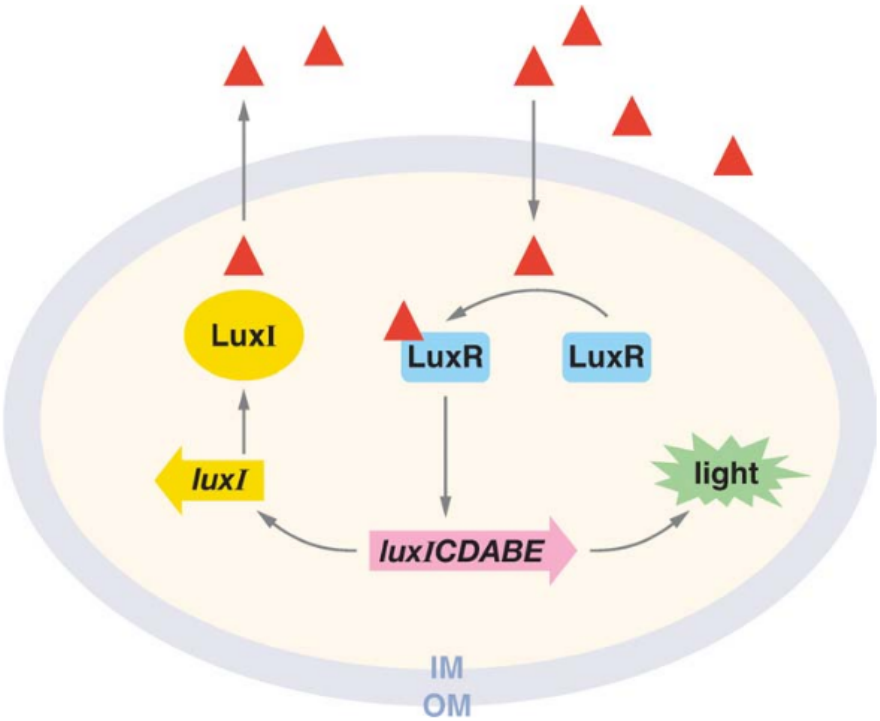

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- Can lead to biofilms, antibiotic production etc.

Public Goods and Cheating

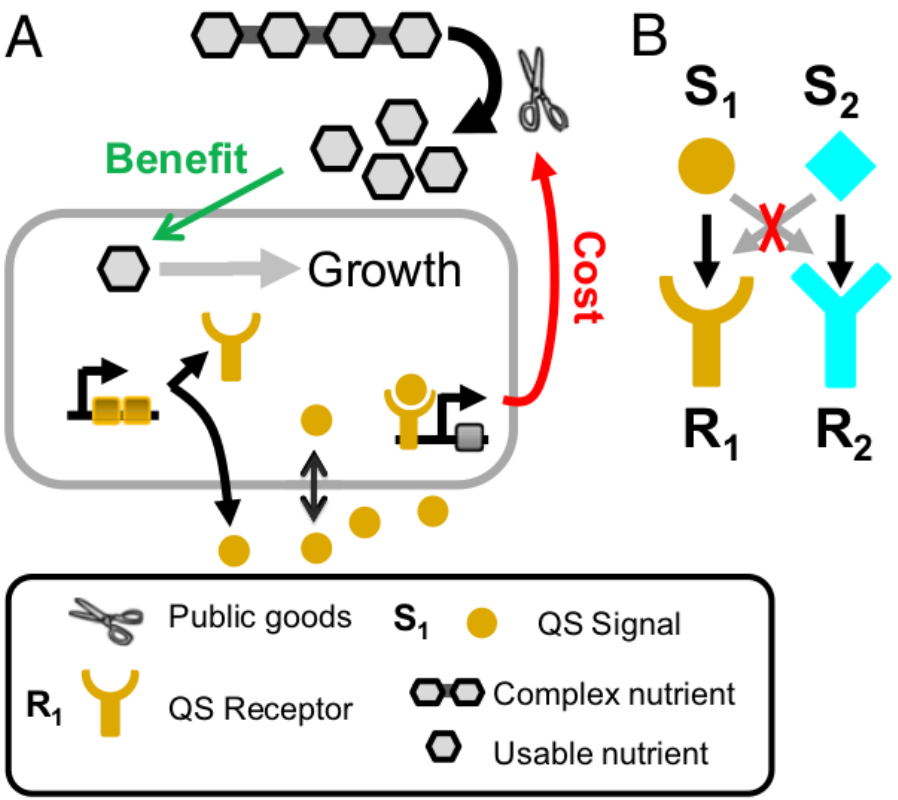

Figure 2: @eldar_2011

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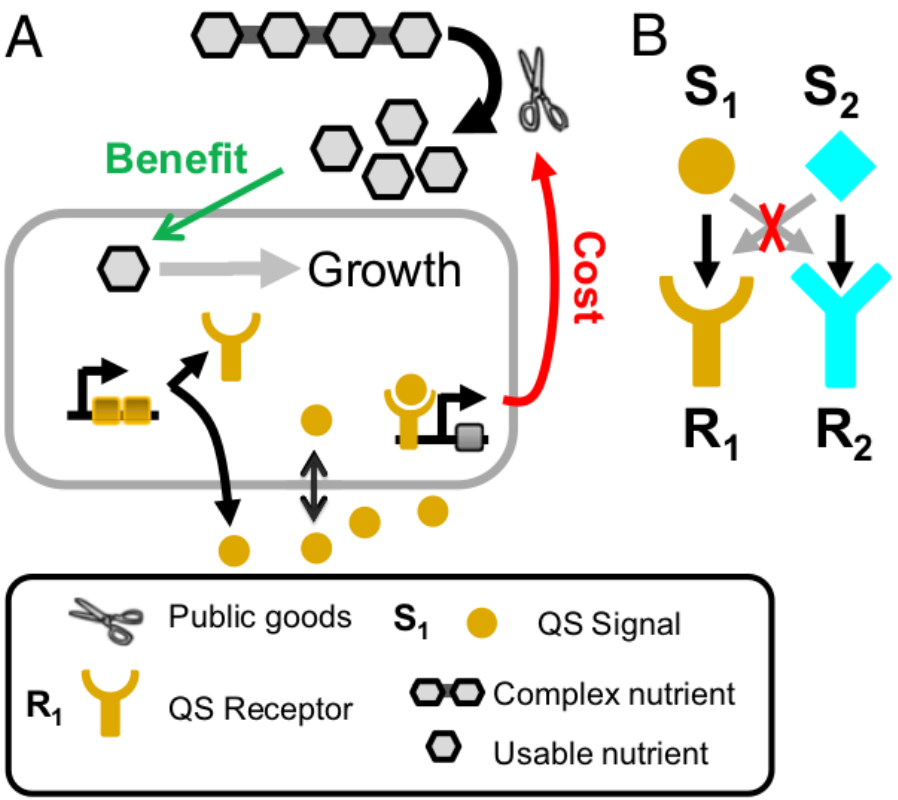

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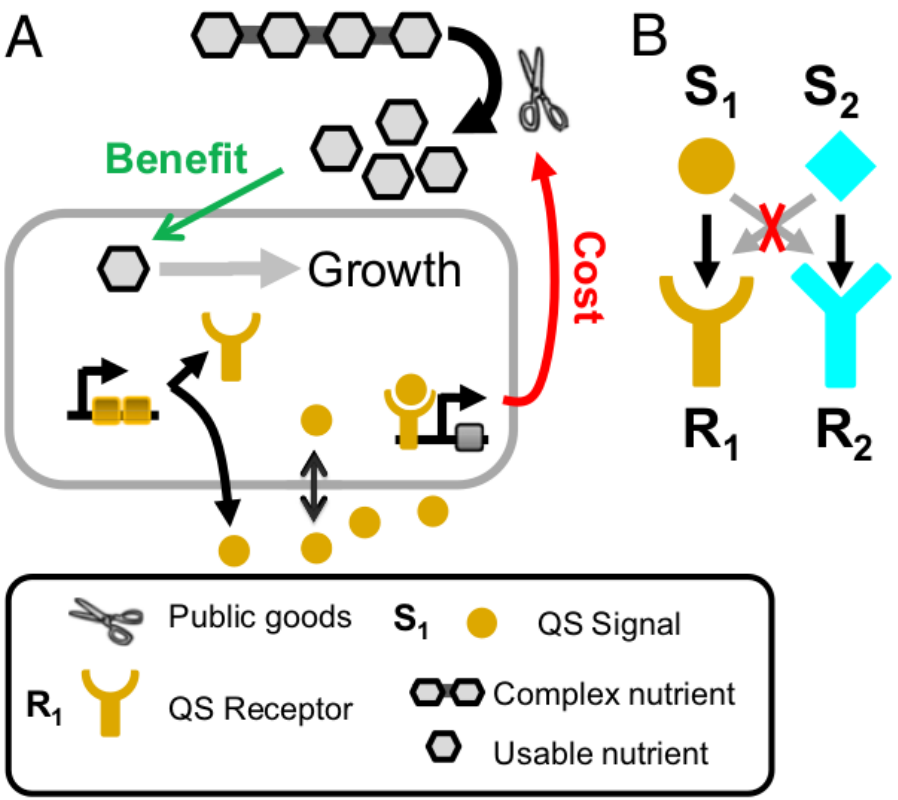

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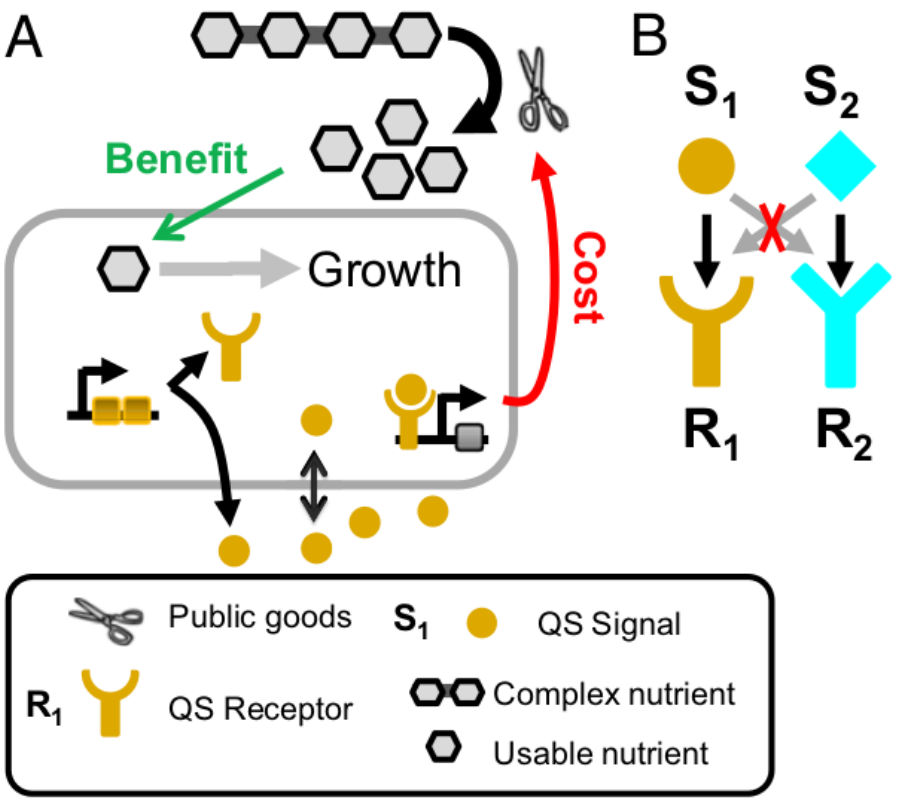

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- Everyone benefits from this even if they don't contribute
- Must produce the receptor, signal molecule and good to contribute
- Cheaters DO prosper (if you are a bacterium)

Who Cares?

- check the discussion from @eldar_2011 for references

Maintaining Freeloaders as a Diversity Reservoir

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Kin Recognition for Strains

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Maintaining Freeloaders as a Diversity Reservoir

Kin Recognition for Strains

Designing Cheaters to Disrupt Pathogen Growth

Methods

Basic ODE Model

Social conflict drives the evolutionary divergence of quorum sensing

Avigdor Eldar[1]

Department of Molecular Microbiology and Biotechnology, Faculty of Life Sciences, Tel Aviv University, Tel Aviv 69978, Israel

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Model Equations

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

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

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

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

Signal-Receptor Activation Matrix K_{ac}

- The interaction term is defined as $R^{active} = \frac{K_{ac}\vec{S}}{K_{RS}+K_{ac}\vec{S}}$

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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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Obligate Cheater

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Custom Matrix

Matrix for 2 strains $R_1R_2S_1$ and R_2S_2

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

Our Work

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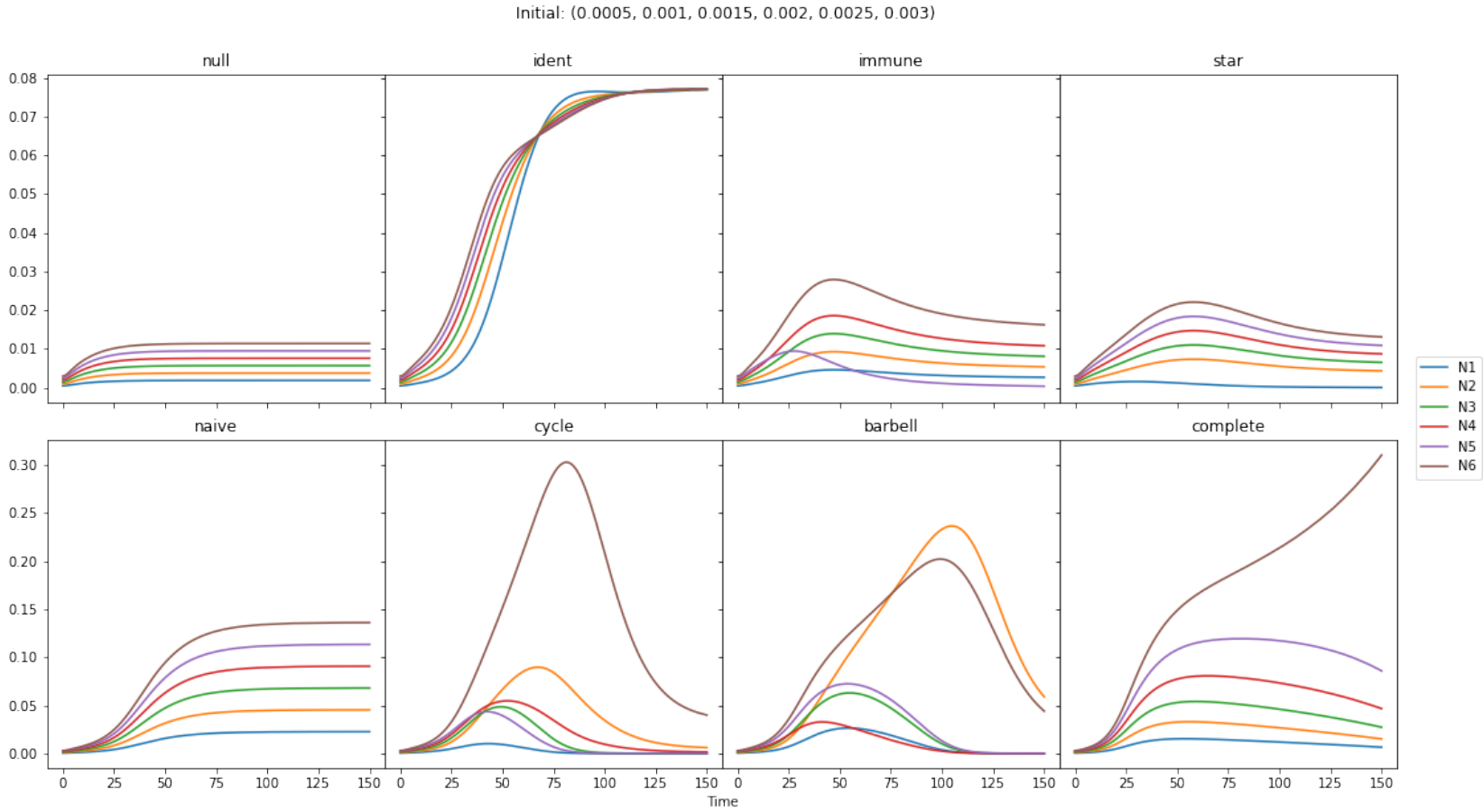
  - Specific patterns and randomly generated K_{ac}
- Examine population structure and model dynamics
- Simulate using gut microbiome data as initial state
- All code/results easily available to use on Github

Results

Comparing Different K_{ac} Matrices



How K_{ac} Sparsity Affects Population Structure

Simulating With Human Gut Microbiome Data

Discussion

Moral of the Study

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Cheating works...

Moral of the Study

Cheating works...

(for bacteria)

Moral of the Study

Cheating works...

(for bacteria)

but cooperating is better!

Bibliography I