How Quorum Sensing Interactions Affect Population Structure

02-712 Final Project

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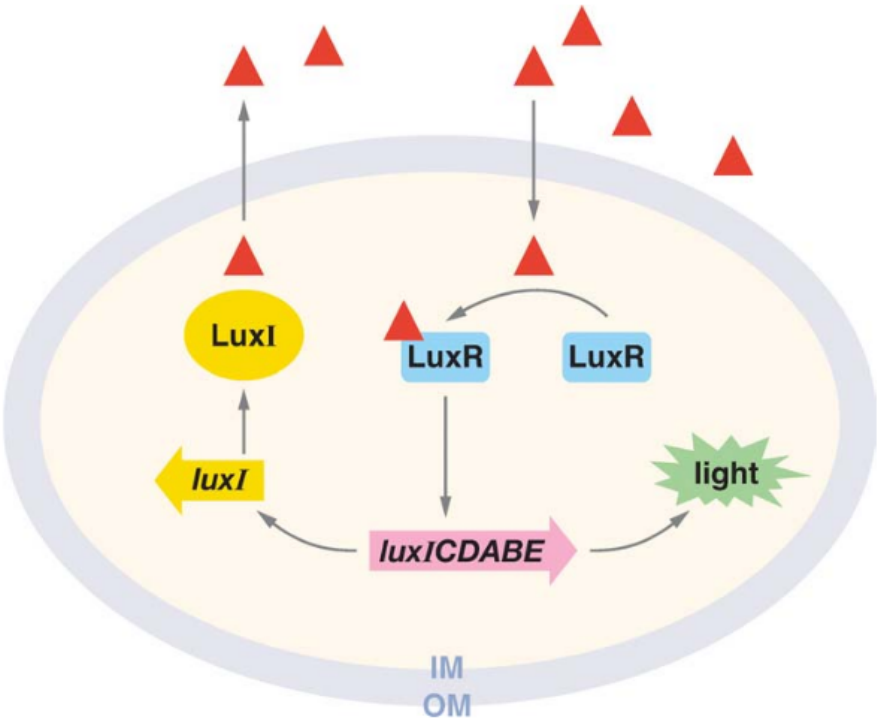
Background

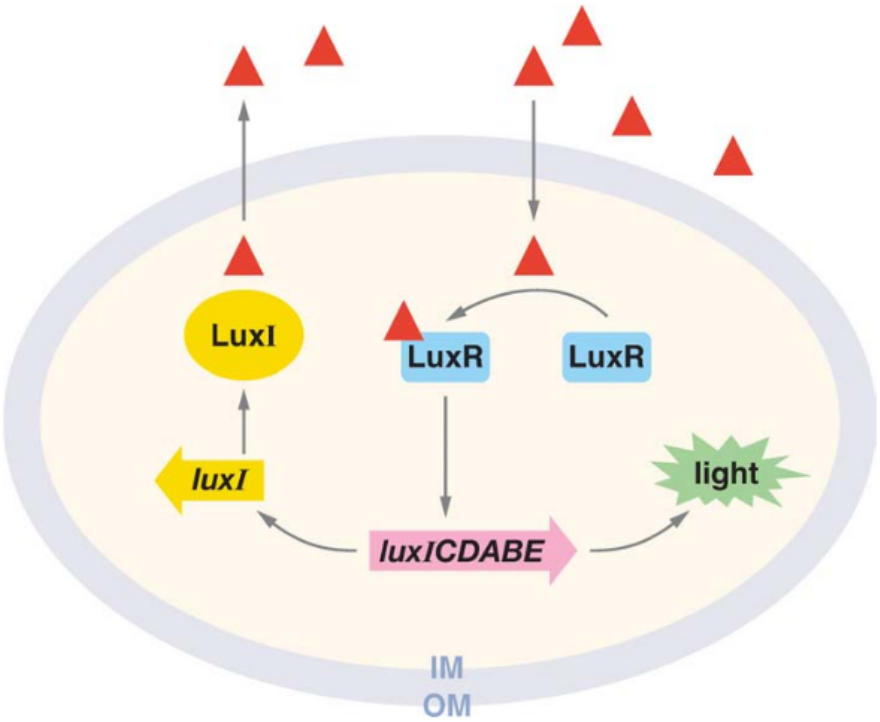
Quorum-Sensing Systems



- Signal-Receptor molecule pairs that modulate gene expression

Figure 1: Waters and Bassler (2005)

Quorum-Sensing Systems



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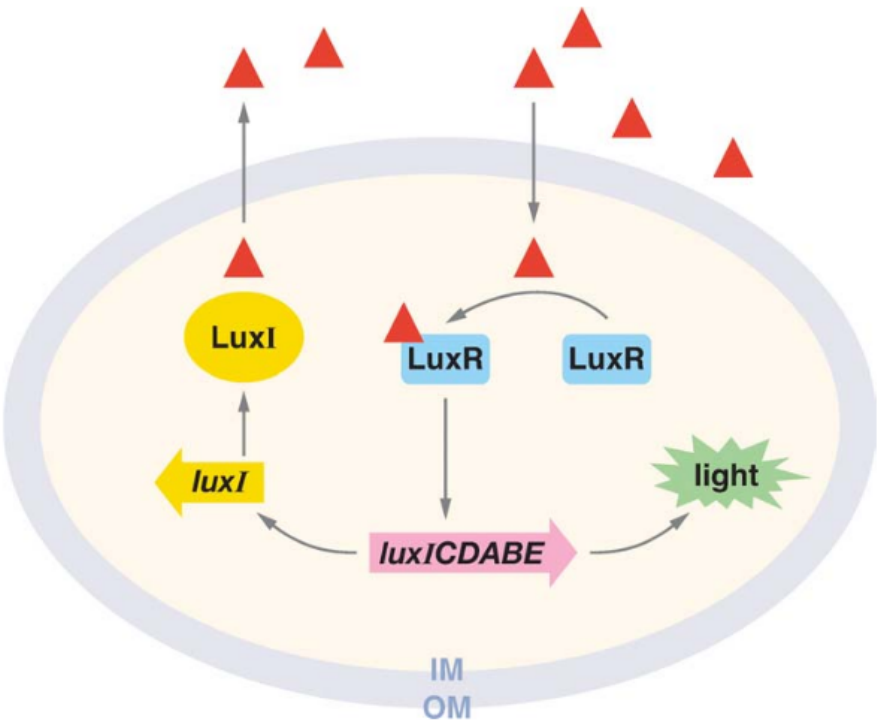


- Signal-Receptor molecule pairs that modulate gene expression
- Once threshold density is reached, enough signal is received to upregulated target genes
- Can lead to biofilms, antibiotic production etc.

Figure 1: Waters and Bassler (2005)

Public Goods and Cheating

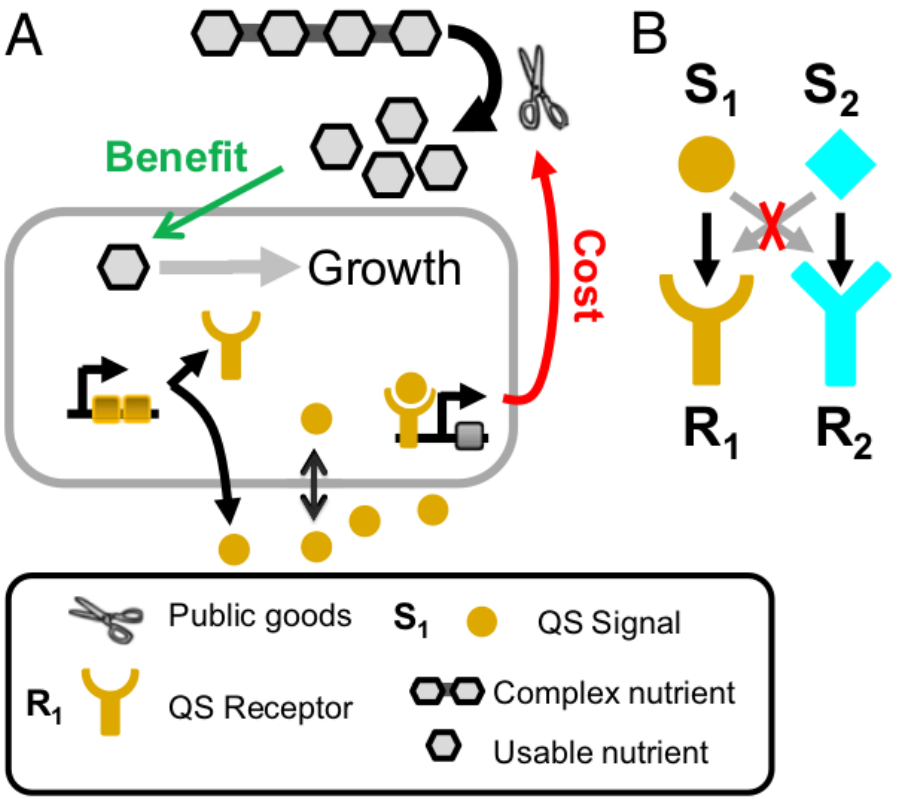
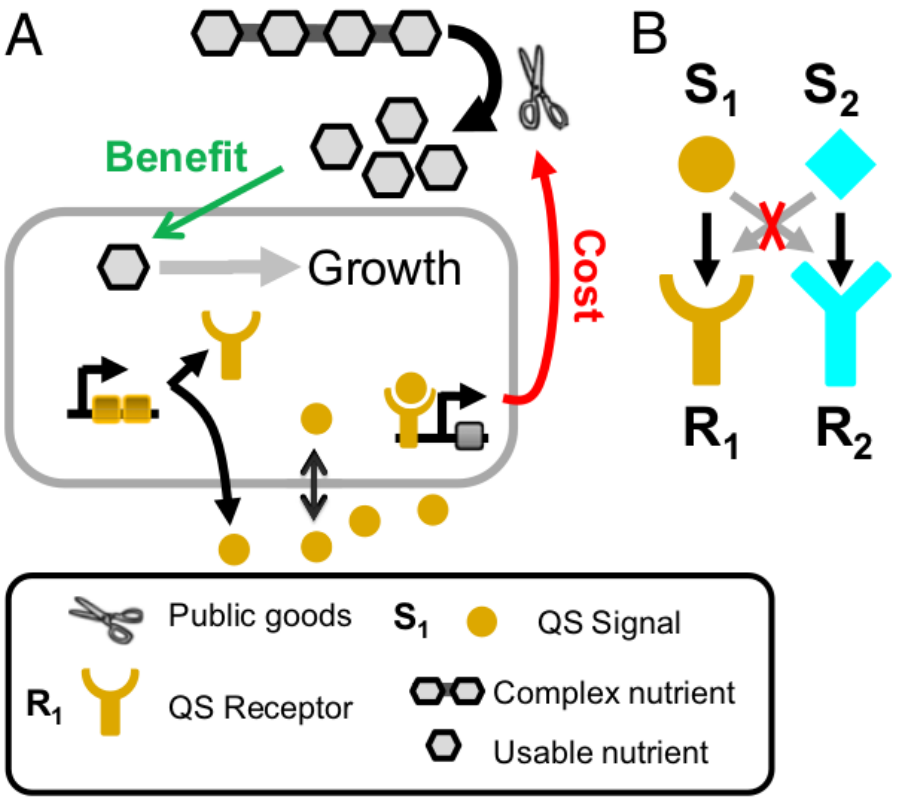


Figure 2: Eldar (2011)

- When quorum is reached, bacteria produce a "public good"

Public Goods and Cheating



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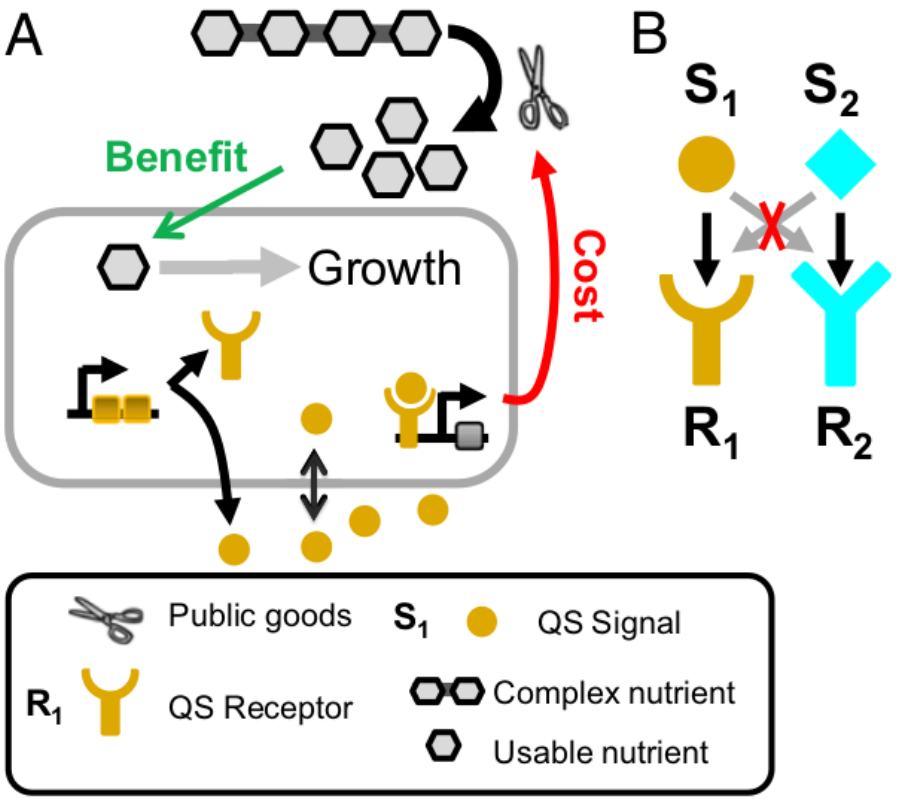

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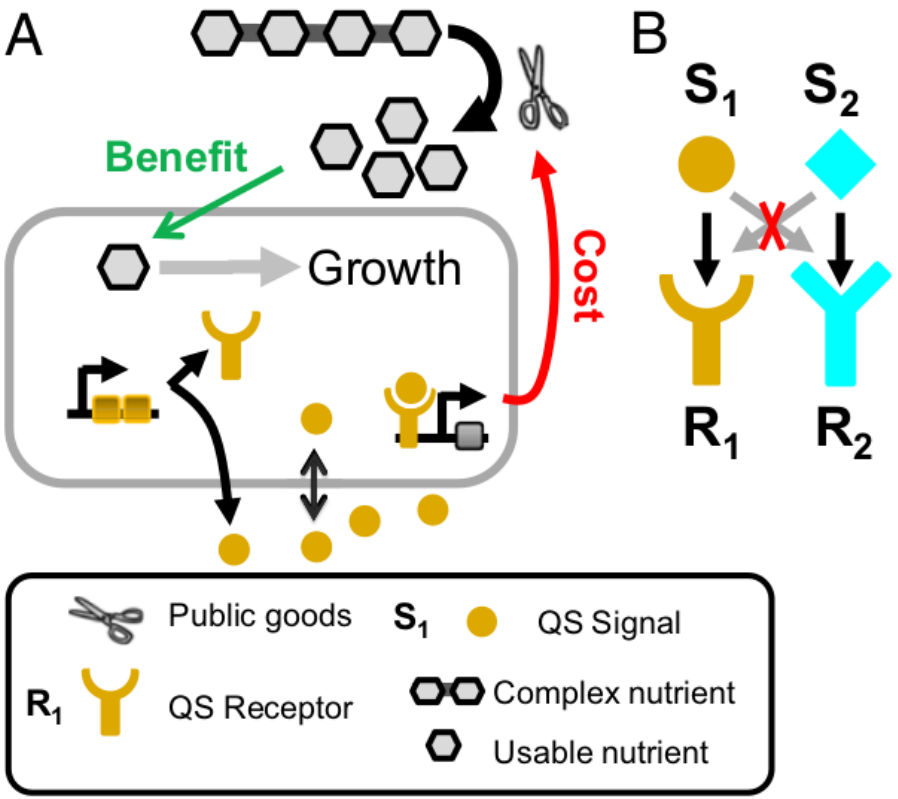

Figure 2: Eldar (2011)

- 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?

- 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

- Equations taken from Eldar (2011)

Basic ODE Model

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Basic ODE Model

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- Equations taken from Eldar (2011)
- Deterministic ODE model of bacteria
- We focused on QS interactions over Evolution

Signal-Receptor Activation Matrix K_{ac}

- Represents all receptors-signal pairs ($R_i S_i$) present in at least 1 OTU in the population

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- Represents all receptors-signal pairs $(R_i S_i)$ present in at least 1 OTU in the population
- Different sets of receptor-signal combinations can produce the same K_{ac}
- K_{ac} is of dimension $|R| \times |S| = |N| \times |N|$

Facultative Cheaters

Matrix for 2 strains R_1S_1 and R_2S_2

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

Facultative Cheaters

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Obligate Cheater

Matrix for 2 strains R_1S_1 and R_0S_0

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Facultative Cheaters

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Obligate Cheater

Matrix for 2 strains R_1S_1 and R_0S_0

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

Custom Matrix

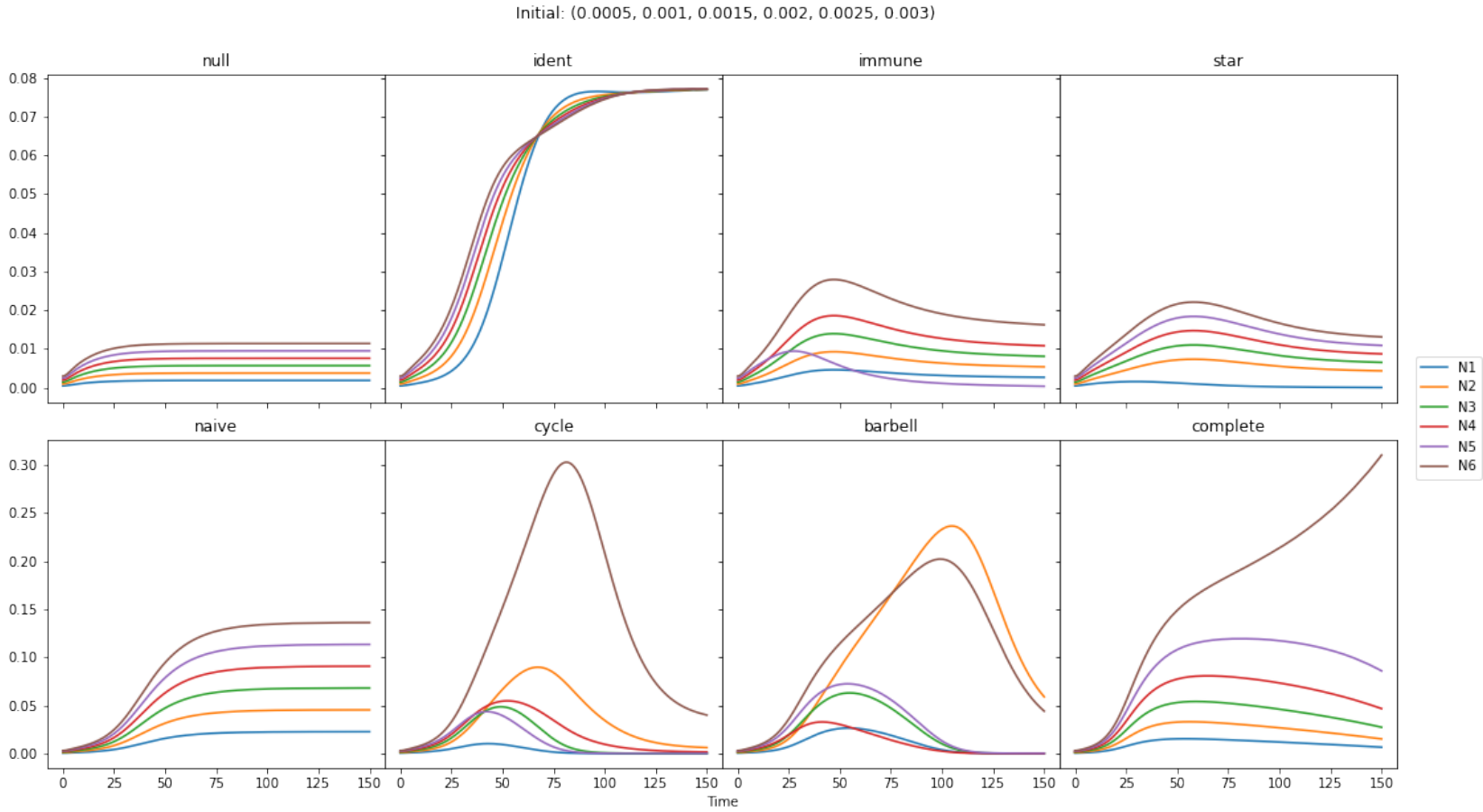
Matrix for 2 strains $R_1R_2S_1$ and R_2S_2

or 3 strains R_1S_1, R_2S_1 and R_2S_2

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

Results

Comparing Different K_{ac} Matrices



How K_{ac} Sparsity Affects Population Structure

Simulating With Human Gut Microbiome Data

Discussion

Chaining K_{ac} has strong effects on model dynamics

- changes can occur independent of sparsity

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Chaining K_{ac} has strong effects on model dynamics

- changes can occur independent of sparsity
- decreasing sparsity does . . .

Moral of the Study

Moral of the Study

Cheating works...

Moral of the Study

Cheating works... (for bacteria)

Moral of the Study

Cheating works... (for bacteria)
but cooperating is better!

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