Logic of Interacting Quorum Sensing Systems in Bacteria

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Short Abstract **— Bacteria release one or more types of signaling molecules into the external environment and sense these molecules when present in the surrounding environment. This phenomenon which enables bacteria to respond in a density-dependent manner is called quorum sensing (QS). QS controls a wide variety of functions in bacteria, including those related to motility, virulence. Interestingly, many bacteria possess more than one QS systems which may enable inter-specie, in addition to intra-specie communication. In this work, we perform simulations to understand the various logical possibilities of QS networks and its impact on dynamics of signal processing in bacteria.**

Keywords **— Quorum sensing, Simulation, Network, Bacteria, Signaling molecules, Responses, Environmental cues.**

I. Background

After discovery of quorum sensing, the notion that bacteria are unicellular organisms has been revised [1]. To get estimate of their numbers in the surrounding environment, bacteria release one or more types of signaling molecules into the external environment. These molecules diffuse away from cells proximity in the environment at low cell densities. However, as cell density increases, bacteria start sensing these molecules released from their neighbours [2]. This molecule based communication is known as quorum sensing (QS) and used by some bacterial species to respond environmental cues.

The bacterial responses include adaptation to nutrients availability, competition with other microorganisms for nutrients and survival, and defence against toxins which are potentially hazardous [3]. Many bacteria possess more than one QS systems and they communicate not only within a species but also across the species [4-6]. The logical complexity in network of interacting different QS systems plays an important role in the dynamics of signal processing and launching functions differently in bacteria.

In this work, we aim to understand what are the various logical possibilities of QS networks? How do different QS systems interplay among each other and come out with appropriate and efficient arrangement of QS systems? and what are the evolutionary factors for selecting appropriate and efficient arrangement in accordance with response demand?

To answer these questions, we frame a mathematical model by using differential equations for analysis and perform simulations to understand different perspectives of various logical possibilities of QS networks in bacteria.

II. Results

Our simulations demonstrate the wide variety of behavior possibilities that are available to the bacterium, upon interaction of multiple QS systems. Specifically, we present our simulation results from QS systems in series, parallel, cooperative, competitive, and those that interact with QS systems from other species.

These logical possibilities play an important role in dynamics of information processing (such as magnification of a signal, integration of different signals, and noise reduction in the system etc) and helps launching number of functions in response to environment cues.

Our results also show that how the steady state dynamics, cost of response, response time , and response at single-cell play an important role in making choices between different possibilities of QS systems for an organism.

III. Conclusion

In this work, we attempt to elucidate the logic of interacting different QS systems and bacterial communication in detail. Our analysis exhibits many physiological aspects of QS systems to understand their functional roles and correlation with network structure.

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References

[1] Miller M, Bassler B (2001) Quorum sensing in bacteria. *Annual Reviews in Microbiology* **55**, 165–99.
[2] Fuqua W, Winans S, Greenberg E (1994) Quorum sensing in bacteria: the LuxR-LuxI family of cell density-responsive transcriptional regulators. *Journal of bacteriology* **176**, 269–75.
[3] Waters C, Bassler B (2005) Quorum sensing: cell-to-cell communication in bacteria. *Annu. Rev. Cell Dev. Biol.* **21**, 319–46.
[4] Galloway W, et al. (2011) Quorum sensing in gram-negative bacteria: Small-molecule modulation of AHL and AI-2 quorum sensing pathways. *Chem. Rev*. **111**, 28-67.
[5] Perez PD, Weiss JT, Hagen SJ (2011) Noise and crosstalk in two quorum-sensing inputs of *Vibrio fischeri*. *BMC Systems Biology* **5**, 153.
[6] Marchand N, Collins CH (2013) Peptide-based communication system enables Escherichia coli to Bacillus megaterium interspecies signaling. *Biotechnol. Bioeng.* **110**, 3003-12.