MATH MATTERS

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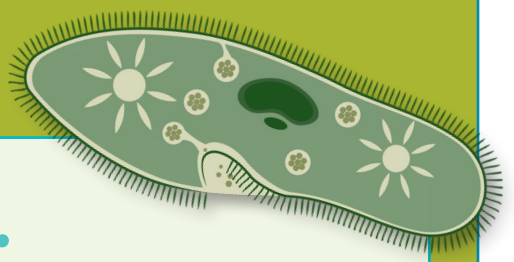


The math behind…

Quorum Sensing Mechanism

Technical terms used:

Quorum sensing, dynamical system, stability analysis, stochastic process, noise, partial differential equation, fluid dynamics

Uses and applications:

Quorum sensing is one of the most visible topics in research for the past few decades. Bacteria (e.g., Pseudomonas aeruginosa, E. coli) communicate to each other through quorum sensing molecules (QSMs) and coordinate certain behavior such as virulence, antibiotic resistance, biofilm formation, and gene expression. To understand this complex biological phenomenon, rigorous mathematical tools are used and have a great impact on the study of anti–quorum sensing, social insects, fungi, immunology, the central nervous system, and much more.

How it works:

There are many amazing facts in nature, and one of them concerns bacterial cells in the human body. There are trillions of human cells that make up each of us, but the surprising reality is that there are tens of trillions of bacterial cells residing in and on a human body. So not more than 10% human cells are present, compared to the huge number of bacterial cells. It would not be foolish if we introduce ourselves as only 10% human but 90% bacteria! Quorum sensing means a cell–cell communication in bacteria, which is used to coordinate group behavior based on population density. This process is regulated by the quorum sensing molecule (QSM), and when it reaches the apparent threshold concentration of QSMs, the cells become induced and undergo gene expressions.

Many proposed mathematical models are based on systems of ordinary differential equations and partial differential equations, which are analyzed and validated by experimental data. Stability analysis and long-term behavior have been studied in the past few years. Network analysis of this quorum sensing has been done from a graph theoretical point of view. Quorum sensing is also connected to biofilms, which we can model as a reaction diffusion equation and study its fluid dynamics. On the other hand, from a stochastic point of view, the origin and the effect of noise also have been studied. Different numerical schemes and simulations are required to investigate this type of complex biochemical phenomenon..

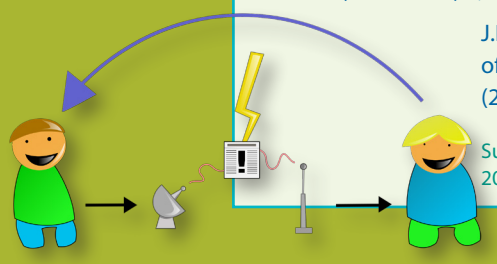
Interesting fact:

Quorum sensing can function as a decision-making process, and it is one of the important facts in collective behavior. Quorum quenching is the process of preventing quorum sensing. It is an important tool for improving the function of a self-organizing network and can coordinate the behavior of autonomous robot swarms.

References:

Miller MB, Bassler BL, Quorum sensing in bacteria. Annu Rev Microbiol, 55 (2001) pp. 165-199.

J.P.Ward, J.R. King, A.J. Koerber, P. Williams, J.M. Croft, and R.E. Sockett, Mathematical modelling of quorum sensing in bacteria, IMA Journal of Mathematics Applied in Medicine and Biology, 18 (2001), pp. 263-292.



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