A Computational Model for Bacterial Swarming

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***Short Abstract* — We have built a cell-based model to study bacterial swarming. The model can easily account for the details at the level of individual cells. A modeling domain is designed that can resemble the swarming conditions properly. We tested the model in the swarming of Myxobacteria, which are commonly found in soil and well studied at biochemical level. The model is validated and has proved its potential to gain insights into bacterial swarming.**

I. BACKGROUND

Many Bacteria can grow from a point inoculum to a spreading colony on agar surfaces containing millions of cells, in a manner known as swarming [1]. Swarming also facilitates bio-film formation and colonization of pathogens in host tissues. During swarming bacteria cells differentiate to be long and flexible, and interact with neighboring cells extensively due to very high cell densities [1].

There has been little understanding on the behavioral algorithm of individual cells that governs and ensures the highly efficient cell flow through dense crowds. Bacterial swarming has usually been modeled as the collective motion of self-propelled particles or rods [2, 3]. However these models can hardly resemble the appropriate biological context or account for the complex biological behavior at individual cell level. For example, the cell density in swarming colonies is so high that each cell normally has to interact with a number of others at any time. Unlike non-biological particles, cells do not conserve momentum upon collisions either.

These difficulties inspire us to build a cell-based model for swarming that can easily account for individual-level details; we also design a modeling domain that resembles the swarming conditions properly.

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II. RESULTS

Our cell-based model represents individual cell as a string of beads connected by elastic springs. An effective energy describes the cell shape. The cell body is therefore flexible to some degree. On top of this cell representation we can incorporate details of cell motility and social interactions, such as the slime-cell interaction, pilus-mediated interaction, etc.

We have tested the model in the swarming of Myxobacteria. Myxobacteria are commonly found in soil and well studied at sub-cellular level, with many details of cell mechanics known. The model is validated by the resulting constant growth of simulated colony, which agrees with experimental observation [4]. We investigate the role of social interactions in facilitating bacterial swarming, quantitatively reproduce the synergism between the two motilities of myxobacteria, and demonstrate that local ordering of cell motion is the key to maintain efficient cell flow in swarming colonies [4]. We further study how the moving algorithm adopted by myxobacteria has evolved due to selection force [5]. The experimentally quantified frequencies of motility oscillations are shown to produce optimum swarming efficiency [5]. These critical tests on our model have proved its potential to gain insights into bacterial swarming.

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