Biophysical analysis of mechanical intercellular interactions discriminates between alternative models of A-motility in *Myxococcus xanthus*

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The mechanism of cell motility in the bacterium *Myxococcus xanthus*, a model organism used to study biofilm self-organization, is not completely understood. Based on recent experimental results, two alternative models for *M. xanthus* A-motility, which differ in the way the cell interacts with the substrate, have been proposed in literature. Using a biophysical model of the cell, this present work allows us to distinguish between the proposed models. Comparisons of mechanical cell interactions in our model with new experimental observations indicate that an elastic coupling between the cell and the substrate is required for A-motility.

I. INTRODUCTION

M. xanthus is a predatory soil bacterium that has been used as the model organism for studying self-organization behavior in prokaryotes. In biofilms, *M. xanthus* cells form dynamic multicellular patterns that require the coordinated surface movement of cells. *M. xanthus* moves on solid surfaces with two independent motility systems – adventurous (A) and social (S) motility. In S-motility, the cell uses the retraction of type IV pili for movement. The mechanism of A-motility is still under investigation. Recent fluorescence experiments have revealed that the A-motility motor proteins form an ordered array of clusters along the cell length [1]. These clusters are hypothesized [2] to be transient adhesion complexes, called focal adhesions. In the focal adhesion model the cell is proposed to form stationary attachments with the underlying substrate and moves forward by tracking along a helical cytoskeleton using the motor proteins. However a different mechanism is proposed in the helical rotor model of A-motility [3]. In this model the cell generates force with the substrate using the frictional contact of the motor protein clusters that move within the cytoplasm and deform the cell membrane. Neither model has been conclusively proven to be correct. Our work investigates the two models of A-motility by implementing their physical equivalent forms into a biophysical model of the *M. xanthus* cell. We hypothesize that the mechanical interaction behavior between a pair of cells is different in both the models and thus comparing the model results with experiments provide insights into the mechanism of A-motility.

II. METHODS AND RESULTS

In our biophysical model we depict each cell by a string of nodes; each node represents a motor protein cluster that drives the cell forward. We implement the helical rotor model of A-motility by introducing a drag force on the nodes that is equivalent to the frictional coupling of the nodes to the substrate. For the focal adhesion model we use elastic attachments between each node and the substrate. These attachments resist transverse movement of the cell nodes by introducing an elastic restoring force.

We have simulated cell-cell collision events between two isolated cells to distinguish between the mechanical interaction behavior of cells in both models. In this collision process one cell (the secondary cell) collides with another cell (the primary cell) obliquely at some point along the length of the primary cell. We have quantified the change in orientation of the primary cell before and after the collision event in both models of A-motility. Our model results indicate that the focal adhesion model of A-motility produces a small change in the primary cell orientation compared to the helical rotor model, due to the restoring force of the elastic attachments. To analyze the actual cell behavior under similar circumstances, we have obtained and quantified time-lapse images of *M. xanthus* cells moving under low cell density conditions. The analysis of the cell collision events from the experimental images indicates a small change in the primary cell orientation as a result of collisions.

III. CONCLUSION

Comparisons between the simulation and experimental results indicate that only the elastic coupling with the substrate can explain the observed cell behavior. Thus, our results support the focal adhesion model as an appropriate representation of the mechanism of *M. xanthus* A-motility.

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