Modeling of proteins sub-cellular localization in *E. coli*

Xiaohua Xu[1] and Rahul Kulkarni[2]

***Short Abstract* — The specific sub-cellular localization of Min proteins is crucial to accurate *E. coli* cell division. We examine how the processes of diffusion, nucleotide exchange and membrane attachment contribute to the precise sub-cellular localizations of Min proteins. Based on previous experimental results we suggest a minimal model analytically providing insight into the physics processes that govern the protein localization in *E. coli* cell. We provide the results of numerical simulations for the system and make connections to the observed experimental phenomenology.**

***Keywords* — cell division, Min protein oscillation**

I. Introduction

SPECIFIC sub-cellular localization of proteins is a vital component of important bacterial processes. In the process of *E. coli* cell division, the accurate division site depends on the interactions of three Min proteins, MinC, MinD and MinE [1-5]. MinC inhibits the formation of the FtsZ ring, a protein that determines the site of cell division, whereas MinD recruits cytoplasmic MinC [6] and MinE [7] onto the cell membrane. MinE functions as a suppressor of the segregation of MinD, which dissociates the membrane associated complexes of MinC and MinD into cytoplasm. The dynamics of MinC follows that of MinD [8]. With the presence of MinE, MinD performs a pole-to-pole oscillation throughout the cell with a period of about 40s [9]. During each oscillation period, MinD molecules accumulate in half of the cell membrane before the dissociation occurs which appears to be a shrinking polar zone towards the end of the cell. Meanwhile the cytoplasmic MinD molecules associate in the opposite end of the cell forming a new polar zone. The oscillation of MinD with MinC from pole to pole ensures that FtsZ ring formation is inhibited at polar area [10] so that the cell division can only occur at near midcell.

II. Results

We built a 1-D model for MinD oscillation in finite cells. We examine how the processes of diffusion, nucleotide exchange, membrane attachment and attachment nucleation contribute to the specific MinD localization in the cell, and how the integration of all physics insights behind each one of the processes provides an understanding to the system. Both the analytical and numerical results suggest that the membrane attachment probability of MinD molecules is at the maximum at the opposite pole of the existing polar zone. This maximum requires careful selection of diffusion constant, nucleotide exchange rate, nucleation number, membrane attachment rate and dissociation rate.

III. Conclusion

The Min proteins sub-cellular localization in *E. coli* cell division is governed by physics processes. Under certain assumptions, the specific localization of MinD new polar zone is a statistically natural result.

[1]Department of Physics, Virginia Polytechnic Institute and State University, Blacksburg, VA USA. E-mail: xxh@vt.edu

[1]Department of Physics, Virginia Polytechnic Institute and State University, Blacksburg, VA USA. E-mail: kulkarni@vt.edu

References

[1] P. A. J. de Boer, R. E. Crossley, and L. I. Rothfield, Cell **56**, 641 (1989).
[2] P. A. J. de Boer, R. E. Crossley, and L. I. Rothfield, J. Bacteriol. **174**, 63 (1992).
[3] E. Bi and J. Lutkenhaus, Nature (London) **354**, 161 (1991).
[4] X. Fu, Y. L. Shih, Y. Zhang, and L. I. Rothfield, Proc. Natl. Acad. Sci. U.S.A. **98**, 980 (2001).
[5] Y. L. Shih, T. Le, and L. Rothfield, Proc. Natl. Acad. Sci. U.S.A. **100**, (2003)
[6] J. Huang, C. Cao, and J. Lutkenhaus, J. Bacteriol. **178**, 5080 (1996).
[7] Z. Hu, E. P. Gogol, and J. Lutkenhaus, Proc. Natl. Acad. Sci. U.S.A. **99**, 6761 (2002).
[8] D. M. Raskin and P. A. J. de Boer, J. Bacteriol. **181**, 6419 (1999).
[9] D. M. Raskin and P. A. J. de Boer, Proc. Natl. Acad. Sci. U.S.A. **96**, 4971-4976 (1999).
[10] E. Bi and J. Lutkenhaus, J. Bacteriol. **175**, 118 (1993)