Stochastic Modeling of Bacterial Cell Size Control and Homeostasis

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Abstract — **Recent studies have revealed the rules controlling cell size homeostasis in bacteria. However, whether these mechanisms apply to growth-defective backgrounds remains an open question. Herein, we propose a Markov chain model describing bacterial growth in wt or growth-defective backgrounds and test some of our predictions experimentally. Our results suggest that, in mutant backgrounds, bacteria separate into populations with different division capabilities, and that the location of the septum is irrelevant to satisfy the so-called incremental rule. In conclusion, we propose a simple phenomenological model to unify the rules of cell size control and homeostasis in wt and growth-defective strains.**

Keywords — **Markov chains, Cell size control, Homeostasis, Growth-defective bacteria**

I. Background

CELL size is a major factor for determining cell function and is regulated by the coordination of growth and division. Recent advances have helped to reveal a how cells sense their sizes and divide at specific locations and times to precisely achieve size homeostasis. However, open questions still remain.

Cell size control based on a "timer" model (cells divide after growing for a specific amount of time [1]) are inconsistent with experimental data about the size-dependent generation time [2,3]. On the other hand, the "sizer" model suggests that cells sense their size and divide following a critical size distribution [1,3]. Some experiments validate this hypothesis: budding yeast controls its size by critical size sensing [4] and there exist a size threshold during mitosis in fission yeast [5]. However, in *E.coli*, Taheri-Araghi et al. have shown that the correlation between the cell size at division and the size at birth falsifies the critical size model [3].

To explain *E.coli* size control, is has been proposed that rod-shaped bacteria follow the so-called incremental rule [3,6,7]. In this model, cells grow, in every cycle, a given size that is independent of the cell size at birth. This growing rule, when coupled with a mid-cell division process, leads to size convergence and homeostasis.

II. Summary of Results

a). We propose a simple stochastic model based on a Markov chain that relies on a single adjustable parameter (division probability) to describe either wild-type or growth-defective bacteria.

b). We confirm experimentally some of our findings in regards of a) cell size distribution, b) cell size at birth distribution, and c) cell size increment vs. cell size at birth distribution using wt and *E. coli* (ΔFtsZ) strains.

c). Our model suggests that in growth-defective backgrounds the bacterial populations split into colonies with distinct division capabilities and that the septum location is filamentous cells is irrelevant to achieve cell size homeostasis.

III. Conclusion

We propose a simple phenomenological model to explain size control quantitatively. The predictions for wt strains are compatible with the incremental rule model. In addition, our model helps to understand the growing properties and size homeostasis in colonies with aberrantly long cells.

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