Optical-trap Based Analysis of Bacterial Motility

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***Short Abstract* — Bacterial Chemotaxis is a model system for studying sensory response. Defining features such as exponentially distributed run and tumble durations, and exact adaptation, were characterized at the population level. However, it is not known whether these features hold at the individual cell level, and what kind of variability exists. Due to limitations in the current microscopic tracking assay for studying individual cells, we developed a novel, optical-trap based assay. Our results show that run and tumble durations are exponentially distributed at the individual cell level, and that a given cell can exhibit several different run speeds.**

***Keywords* — Bacterial Chemotaxis, *E. coli*, Optical tweezers, individual variability**

I. Background

Bacterial chemotaxis was first studied in a quantitative manner using the capillary assay, where number of cells that swim up the gradient inside a thin glass capillary is counted at the bulk-culture level. Further developments in chemotaxis studies followed the invention of the 3-D tracking microscope [1], along with 2-D tracking using conventional microscopes [2]. In these assays, swimming traces of individual cells are recorded, from which runs and tumbles can be distinguished. Defining features of bacterial chemotaxis in *E. coli*, such as exponentially distributed dwell times of runs and tumbles [1], as well as exact adaptation to step increase in attractant concentration [3], have been characterized with this assay.

Although intrinsically a single-cell technique, microscopic tracking assay requires population-averaging in practice, because tracking time for a given cell is typically limited to less than a minute. In order to re-examine bacterial chemotaxis at the individual cell level, and to look for features that are possibly averaged out in population statistics, we have developed a novel, optical-trap based single-cell assay of bacterial motility.

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II. Method

In our assay, we monitor the motility of a bacterial cell that is optically trapped inside a fluidic chamber. Although held at a fixed position, the body of the trapped cell undergoes counter-movement to the flagellar bundle movement. The trapped cell body exhibits distinct movement corresponding to "runs" and "tumbles" of a freely swimming cell, which we have directly observed by simultaneously recording video images of a fluorescently labeled, optically-trapped cell. Run/tumble detection by the optical-trap assay is also compared to that of the 2-D tracking assay. Using this assay, we have monitored motility of individual *E. coli* cells for up to one hour, with reduced oxygen content in the medium preventing optical damage due to the trapping light.

III. Results

Using the optical trapping essay, we are able to track the motility of individual *E. coli* cells for long periods of time. Run and tumble durations are exponentially distributed for individual cells, with individual variability in the population. In addition, the high-resolution nature of the optical trap measurement revealed a motile behavior that is more complex than the conventional run/tumble approximation. Our measurements suggest that *E. coli* cells can swim at different speeds depending on the direction of the bundle formation with respect to the cell body, and that swimming speed in a given direction may also vary depending on the number of flagella participating in the bundle.

References

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