Bacterial flagellar motor adaptation and implication for the motor ultrasensitivity

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***Short Abstract* —The flagellar motor of *Escherichia coli* adapts to changes in the steady-state level of the chemotaxis response regulator, CheY-P, by adjusting the number of FliM molecules to which CheY-P binds. Previous measurements of motor ultrasensitivity have been made on cells containing different amounts of CheY-P and, thus, different amounts of FliM in flagellar motors. Here, we designed an experiment to measure the sensitivity of motors containing fixed amounts of FliM, finding Hill coefficients about twice as large as those observed before. This ultrasensitivity provides further insights into the motor switching mechanism and plays important roles in chemotaxis signal amplification and coordination of multiple motors. The Hill coefficients observed here appear to be the highest known for allosteric protein complexes, either biological or synthetic. Extreme motor ultrasensitivity broadens our understanding of mechanisms of allostery and serves as an inspiration for future design of synthetic protein switches.**

***Keywords* — bacterial flagellar motor, chemotaxis, allostery**

I. Introduction

The flagellar motor is very sensitive to the concentration of chemotaxis response regulator CheY-P. This sensitivity is commonly characterized by a Hill coefficient, *n*, obtained by fitting the motor CW bias vs. [CheY-P] relationship with the Hill function $1/(1+(K_{1/2}/[\text{CheY-P}])^n))$, where $K_{1/2}$ is the concentration at which CW bias is 0.5. Measurements in bacterial populations reported values of the Hill coefficient ranging from 3.5 to 5.5 [1, 2]. Measurements with single cells removed complications due to averaging over cell populations and reported a value of the Hill coefficient of 10.3 [3]. Recently, the flagellar motor was found to partially adapt to variations in the concentration of CheY-P by changing the number of FliM subunits in its switch complex [4]. Therefore, the measurements made with single cells were actually measurements of cells that had adapted to different levels of CheY-P, representing an average over motors with different complements of FliM. To learn the actual response of the motor, the input-output relationship should be measured for motors with a fixed number of FliM subunits.

II. Results

Here, we designed an experiment that used a bead assay to accomplish this task, by measuring the step response of an *E. coli* K-12 strain lacking the chemotaxis adaptation genes. We found that the sensitivity for pre-adapted motor with a specific number of FliM units is actually about a factor of two larger than the most recent single cell measurement.

III. Conclusion

The ultrasensitivity (high switching cooperativity) observed here (Hill coefficient n ~21) is easily the highest found among allosteric protein complexes. We expect this ultrasensitivity will provide further insights into mechanisms of allostery and inspire future design of synthetic protein switches.

References

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