[C1] Energy dissipation in an adaptive molecular circuit

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The ability to monitor nutrient and other environmental conditions with high sensitivity is crucial for cell growth and survival. Sensory adaptation allows a cell to recover its sensitivity after a transient response to a shift in the strength of extracellular stimulus. The working principles of adaptation have been established previously based on rate equations which do not consider fluctuations in a thermal environment. Recently, Lan et al (2012 Nat. Phys. 8 422–8) performed a detailed analysis of a stochastic model for the Escherichia coli sensory network. They showed that accurate adaptation is possible only when the system operates in a nonequilibrium steady-state (NESS). They further proposed an energy-speed-accuracy (ESA) trade-off relation. We present here analytic results on the NESS of the model through a mapping to a one- dimensional birth-death process. An exact expression for the entropy production rate is also derived. Based on these results, we are able to discuss the ESA relation in a more general setting. Our study suggests that the adaptation error can be reduced exponentially as the methylation range increases. Finally, we show that a nonequilibrium phase transition exists in the infinite methylation range limit, despite the fact that the model contains only two discrete variables.