Regulatory control and the costs and benefits of biochemical noise

SORIN TANASE-NICOLA, University of Michigan, PIETER REIN TEN WOLDE,
Institute for Atomic and Molecular Physics, AMOLF, The Netherlands — Experiments in recent years have vividly demonstrated that gene expression can be highly stochastic. We present a mathematical model that makes it possible to quantify the effect of protein concentration fluctuations on the growth rate of a population of genetically identical cells. The model predicts that the population's growth rate depends on how the growth rate of a single cell varies with protein concentration, the variance of the protein concentration fluctuations, and the correlation time of these fluctuations. The model shows that when the average concentration of a protein is close to the value that maximizes the growth rate, fluctuations in its concentration always reduce the growth rate. However, when the average protein concentration deviates sufficiently from the optimal level, fluctuations can enhance the growth rate of the population, even when the growth rate of a cell depends linearly on the protein concentration. We also apply our model to perform a cost-benefit analysis of gene regulatory control. Our analysis predicts that the optimal expression level of a gene regulatory protein is determined by the trade-off between the cost of synthesizing the regulatory protein and the benefit of minimizing the fluctuations in the expression of its target gene.

Sorin Tanase-Nicola
University of Michigan

Date submitted: 05 Dec 2007   Electronic form version 1.4