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Fitness effects of fluctuations in biochemical networks

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The concentration of many cellular components fluctuates not only as a response to external and internal inputs but also due to random birth and death events of individual molecules. This biochemical noise affects the capacity of every individual cell in a population to respond and adapt to the environment. While the sources and effects of biochemical fluctuations on individual cells have been intensively studied, the effects of noise on the growth rate of a population of cells are much less understood. We present a model of the cell cycle in which the growth and division of individual cells are coupled with the noisy dynamics of their internal components. The model allows us to compute the contribution of the biochemical noise to the average growth rate of a population of cells as a function of the noise strength and the correlation time of the fluctuations. We show that, due to fluctuations, the growth rate of a population of cells is always larger than the average growth rate of a individual cell and can be larger even than a corresponding deterministic model. In most relevant cases it is assumed that the average concentration of a cellular component is close to a value that maximizes the population growth as given by the external, environmental, conditions and the internal cellular regulation. In such cases we show that contribution of fluctuations to the growth rate is negative and increases with the sensitivity of the biochemical networks to the noise sources and the noise correlation time. We also discuss how the selection pressure due to fluctuations affects the structure and parameters of genetic regulatory networks.