

Effective potential for cellular size control

S. Burov

Bar Ilan University

For various species of biological cells, experimental observations indicate the existence of universal distributions of the cellular size, scaling relations between the cell-size moments and simple rules for the cell-size control. We address a class of models for the control of cell division, and present the steady state distributions. By introducing concepts such as effective force and potential, we are able to address the appearance of scaling collapse of different distributions and the connection between various moments of the cell-size. The effective potential dictates the properties of the cell size distribution, which attains the regular Boltzmann form. Our approach allows us to derive strict bounds which a potential cell-size control scenario must meet in order to yield a steady state distribution. The so-called "adder" model for cell-size control exhibits the weakest control that still enables the existence of stable size distribution, a fact that might explain the relative "popularity" of this scenario for different cells. While symmetric cellular division corresponds to a particle in an effective potential, the asymmetric division is described by a particle in effective potential that is performing stochastic jumps between two states. The mathematical formalism that we use is a continuous approximation for for general non-linear stochastic and deterministic discrete maps. For the stochastic map, by successively applying the Itô lemma, we obtain a Langevin type of equation. Specifically, we show that for a general class of non-linear maps, the Langevin description involves multiplicative noise. The multiplicative nature of the noise implies additional effective forces, not present in the absence of noise. We further exploit the continuum description and provide an explicit formula for the stable distribution of the stochastic map. Our results are in good agreement with numerical simulations of several maps. Applications of the presented formalism are not limited to description of cellular growth and can be applied to any system where stochasticity and temporal discreteness are of essence.

[1] D.A. Kessler and S. Burov, arXiv:1701.01725.

[2] D.A. Kessler and S. Burov, arXiv:1612.08703.