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On the relationship between cell cycle analysis with ergodic principles and age-structured cell population models

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Abstract

Cyclic processes, in particular the cell cycle, are of great importance in cell biology. Continued improvement in cell population analysis methods like fluorescence microscopy, flow cytometry, CyTOF or single-cell omics made mathematical methods based on ergodic principles a powerful tool in studying these processes. In this paper, we establish the relationship between cell cycle analysis with ergodic principles and age structured population models. To this end, we describe the progression of a single cell through the cell cycle by a stochastic differential equation on a one dimensional manifold in the high dimensional dataspace of cell cycle markers. Given the assumption that the cell population is in a steady state, we derive transformation rules which transform the number density on the manifold to the steady state number density of age structured population models. Our theory facilitates the study of cell cycle dependent processes including local molecular events, cell death and cell division from high dimensional "snapshot" data. Ergodic analysis can in general be applied to every process that exhibits a steady state distribution. By combining ergodic analysis with age structured population models we furthermore provide the theoretic basis for extensions of ergodic principles to distribution that deviate from their steady state.

Keywords: heterogeneity, cell cycle, cell population

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