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Cell lineage statistics and fitness with incomplete population trees

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Cell lineage statistics is a powerful tool for inferring cellular parameters, such as division rate, death rate or the population growth rate. Yet, in practice such an analysis suffers from a basic problem: how should we treat incomplete lineages that do not survive until the end of the experiment? Here, we develop a model-independent theoretical framework to address this issue. This framework provides a linear response relation which quantifies the reduction of population growth rate due to the inclusion of cell death. We show how to quantify fitness landscape, survivor bias and selection for arbitrary cell traits from cell lineage statistics in the presence of death, and we test this method using an experimental data set in which a cell population is exposed to a drug that kills a large fraction of the population. This analysis reveals that failing to properly account for dead lineages can lead to misleading fitness estimations. For simple trait dynamics, we prove and illustrate numerically that the fitness landscape and the survivor bias can in addition be used for the non-parametric estimation of the division and death rates, using only lineage histories. Further, in the context of cell size control, we obtain generalizations of Powell's relation that link the distributions of generation times with the population growth rate, and show that the survivor bias can sometimes conceal the adder property, namely the constant increment of volume between birth and division.

Affiliation de l'auteur principal

CNRS

Auteur principal: LACOSTE, David (CNRS-ESPCI)

Co-auteurs: GENTHON, Arthur; PELITI, Luca; NOZOE, Takashi

Orateur: LACOSTE, David (CNRS-ESPCI)

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