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Matched Asymptotic Analysis of the Luria–Delbrück Distribution in a Reversible Fluctuation Assay

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We study a fluctuation test where cell colonies grow from a single cell to a specified population size before undergoing treatment. During growth, cells may acquire resistance to treatment and pass it to their offspring with a small probability. Unlike the classical Luria–Delbrück test, which assumes irreversible resistance, our model allows resistant cells to revert to a drug-sensitive state. This modification, motivated by recent research on drug resistance in cancer and microbial cells, does not alter the central part of the Luria–Delbrück distribution, where the Landau probability density function approximation remains applicable. However, the right tail of the distribution deviates from the power law of the Landau distribution, with the correction factor given by the Landau cumulative distribution function. Using singular perturbation theory and asymptotic matching, we derive uniformly valid approximations and describe tail corrections for populations with different initial cell states.

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