Noise-dependent developmental plasticity and the evolution of novel morphologies in B. subtilis.

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Developmental processes can change, sometimes drastically, in response to environmental conditions or mutations. A central question in evolution is how this developmental 'plasticity' is related to the evolution of new morphologies over longer timescales. B. subtilis sporulation represents an ideal model developmental system to address this problem. In B. subtilis, sporulating cells each produce a single mature spore. Here we use time-lapse fluorescence microscopy on individual cells to investigate the differentiation of the cell into forespore and mother-cell compartments and the dependence of this process on inter-compartmental signaling. We find that when signaling is delayed cells employ a spectrum of "backup" responses which are activated in different sub-populations. These responses include a previously unknown process in which chromosome replication re-initiates, leading either to an additional sporulation attempt or to vegetative division. When signaling is sufficiently delayed, and increased, a fraction of the population exhibits the simultaneous development of two "twin" spores, from a single cell. Twin sporulation in B. subtilis appears similar to multi-spore development in other, polysporogeneous, species. By analyzing the timing and amplitude of gene expression, inter-compartmental signaling, and chromosome replication and translocation events in individual cells of both wild-type and mutant B. subtilis backgrounds, we were able to understand the molecular mechanisms responsible for twin spore development, and predict specific additional mutations that would increase its penetrance. These results show, at the molecular level, how regulatory perturbation of a single gene can reveal underlying developmental plasticity and how further mutations can stabilize this alternative developmental program, allowing the evolution of a new morphology.