345h The Dynamics of Single-Substrate Continuous Cultures: an Integrated Model of Bacterial Cell

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When a chemostat is perturbed from its steady state, it displays complex dynamics. For instance, if the identity of the growth-limiting substrate is switched abruptly, the substrate concentration and cell density undergo a pronounced excursion from the steady state that can last several days. These dynamics occur because certain physiological variables respond slowly. In the literature, several physiological variables have been postulated as potential sources of the slow response. These include transport enzymes, ribosomes, and adenine nucleotides.

In previous work, we studied the role of transport enzymes by considering experiments in which low levels of the transport enzyme limits growth (Shoemaker et al, 2003). It was shown that the long lags could occur because transport enzyme synthesis is autocatalytic. A model was developed to account for transport enzyme synthesis, which captured these transients quantitatively. We then extended the model to account for experiments in which the lags persisted even if the transport levels were high (Gupta et al, 2005). In this case, the growth rates appear to be limited by the protein synthetic machinery (ribosomes). We showed that an extended model taking due account of ribosomes synthesis could capture these transients qualitatively.

In this work, we attempt to understand the manner in which the cell allocates the metabolites to respiration, growth, and excretion. Since the cell frequently consumes excess substrate, it is unable to convert all the metabolites to proteins. The excess substrate in the cell is then discharged as partially oxidized metabolites. To understand this phenomenon, we have further extended our model by including adenine nucleotides as additional variables. We show that the resultant energy balance then imposes constraints which determine the relative rates of protein synthesis, metabolite excretion, and respiration.

References:

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