Hysteresis in Bacterial Chemotaxis

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When exposed to a time-periodic chemical signal, an E.coli cell responds by modulating its receptor activity in a similar time-periodic manner. But there is a phase lag between the applied signal and activity response. We study the variation of activity amplitude and phase lag as a function of applied frequency , using numerical simulations. The amplitude increases with , reaches a plateau and then decreases again for large . The phase lag increases monotonically with and finally saturates to 3/2 when is large. The activity is no more a single-valued function of the attractant signal, and plotting activity vs attractant concentration over one complete time period generates a loop. We monitor the loop area as a function of and find two peaks for small and large and a sharp minimum at intermediate values. We explain these results from an interplay between the timescales associated with adaptation, activity switching and applied signal variation. In particular, for very large the quasi-equilibrium approximation for activity dynamics breaks down, which has not been explored in earlier studies. We perform analytical calculation in this limit and find good agreement with our simulation results.

Reference:

Pramanik, R., Yadav, R.K. Chatterjee, S. Dynamics of chemoreceptor activity with time-periodic attractant field. Eur. Phys. J. E 48, 60 (2025). https://doi.org/10.1140/epje/s10189-025-00525-z