Abstract

The formation of structures in living organisms is addressed within the framework of far-from-equilibrium chemical systems using methods of statistical physics, such as kinetic theory and stochastic methods, at an intermediate, mesocopic scale. Three directions are explored. For the purpose of investigating the stochastic elimination of a fast variable, a fast species is introduced in a nonlinear chemical mechanism. The fluctuations of the slow species using Langevin equations and a master equation are not correctly predicted by the reduced mechanism. The coupling between the fluctuations and the nonlinearities of deterministic dynamics makes the use of the quasi-steady-state approximation delicate when the studied system requires a good control such as in fluorescence correlation spectroscopy (FCS). A submicrometric Turing pattern is simulated in a concentrated system in order to refute certain objections to Turing's model regarding the preservation of proportions in embryos. Assuming an appropriate role of the solvent in the chemical mechanism is sufficient to control the wavelength of the structure by monitoring the concentration of the solution. The results can be exploited to design materials with controlled submicrometric properties in chemical engineering. Following a biomimetic approach, experimental conditions leading to the termination of the Turing structure associated with a decrease of the wavelength are proposed. The sensitivity of the Fisher-Kolmogorov, Petrovsky, Piskunov wave front to small perturbations is used to characterize the effects of the deviation from the dilution limit on diffusion. As a result, the shift of the concentration profiles of two species associated with different diffusion coefficients is a well-adapted criterion to detect perturbations induced by high concentrations. Contrary to the results of a deterministic description, the front speed deduced from the master equation in the dilute case sensitively depends on the diffusion coefficient of the consumed species. In the case of a concentrated solution, the properties of the wave front obtained in the dilute case remain valid but are mitigated by cross-diffusion terms which reduce the impact of different diffusion coefficients.

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