Contraction of stochasticity on hierarchical kinetic networks

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Kinetic networks are widely used for studying complex systems. Since the selection of network for a real system is often not unique, a concern is raised whether and under which conditions hierarchical networks will give the same experimentally measured fluctuating behaviors and identical fluctuation related properties. To clarify these questions, we introduce stochasticity into the traditional lumping analysis, generalize it from rate equations to chemical master equations and stochastic differential equations, and extract the fluctuation relations between kinetically and thermodynamically equivalent networks under intrinsic and extrinsic noises. The results provide a theoretical basis for the legitimate use of low-dimensional models in the studies of macromolecular fluctuations and, more generally, for exploring stochastic features in different levels of contracted networks in chemical and biological kinetic systems. As examples, the theory is applied to account for the behaviors of ion channels under intrinsic noises and biological receptors subject to extrinsic noises.