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A framework towards understanding mesoscopic phenomena: Emergent unpredictability, symmetry breaking and dynamics across scales

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Abstract

By integrating four lines of thoughts: symmetry breaking originally advanced by Anderson, bifurcation from nonlinear dynamical systems, Landau's phenomenological theory of phase transition, and the mechanism of emergent rare events first studied by Kramers, we introduce a possible framework for understanding *mesoscopic dynamics* that links (*i*) fast microscopic (lower level) motions, (*ii*) movements within each basin-of-attraction at the mid-level, and (*iii*) higher-level rare transitions between neighboring basins, which have slow rates that decrease exponentially with the size of the system. In this mesoscopic framework, the fast dynamics is represented by a rapidly varying stochastic process and the mid-level by a nonlinear dynamics. Multiple attractors arise as emergent properties of the nonlinear systems. The interplay between the stochastic element and nonlinearity, the essence of Kramers' theory, leads to successive jump-like transitions among different basins. We argue each transition is a dynamic symmetry breaking, with the potential of exhibiting Thom-Zeeman catastrophe as well as phase transition with the breakdown of ergodicity (e.g., cell differentiation). The slow-time dynamics of the nonlinear mesoscopic system

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