Phase Transitions, Non-equilibrium Fluctuations and Broken Detailed Balance in Biological Systems

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Living cells are kept far out of equilibrium by metabolic processes and energy-consuming molecular motors that generate forces to drive the machinery behind various cellular processes. Such active processes give rise to both directed motion and stochastic fluctuations in living systems at both intracellular and extracellular scales. We describe recent advances both in theoretical modeling of such activity, as well as experiments on reconstituted *in vitro* acto-myosin networks and living cells. We show how internal force generation in cellular networks can both control network stability and give rise to diffusive-like motion. We show that active stresses in model networks can also lead to a novel percolation-like transition that exhibits features of both first- and second-order phase transitions. As a result of enzymatic activity at the molecular scale, living systems characteristically violate *detailed balance*, a fundamental principle of equilibrium statistical mechanics. We show how this leads to violations of detailed balance at the meso-scale in living systems.