MAR13-2012-020617

Abstract for an Invited Paper
for the MAR13 Meeting of
the American Physical Society

Hard limits on control in fluctuating systems

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All intracellular processes involve components present in low numbers, creating spontaneous fluctuations that in turn can enslave the components present in high numbers. The mechanisms are often complex, with reaction rates that depend nonlinearly on concentrations, indirect feedback loops, and distributed delays. Most systems are also sparsely characterized, with a few steps known in detail but many important interactions not even identified. I will present exact analytical mathematical frameworks for deriving limits on behavior in such systems, for example showing how hard it is to tightly control processes that involve bursts, delays, or finite signaling rates - regardless of the nature of the downstream chemical networks. I will also discuss various ways of designing experiments to rigorously exploit conditional independences in fluctuations to infer underlying mechanisms, without having to guess the nature of feedback loops or interacting processes.