MAR11-2010-008492

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Can Simple Biophysical Principles Yield Complicated Biological Functions?

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About once a year, a new regulatory paradigm is discovered in cell biology. As of last count, eukaryotic cells have more than 40 distinct ways of regulating protein concentration and function. Regulatory possibilities include site-specific phosphorylation, epigenetics, alternative splicing, mRNA (re)localization, and modulation of nucleo-cytoplasmic transport. This raises a simple question. Do all the remarkable things cells do, require an intricately choreographed supporting cast of hundreds of molecular machines and associated signaling networks? Alternatively, are there a few simple biophysical principles that can generate apparently very complicated cellular behaviors and functions? I'll discuss two problems, spatial organization of the bacterial chemotaxis system and nucleo-cytoplasmic transport, where the latter might be true. In both cases, the ability to precisely quantify biological organization and function, at the single-molecule level, helped to find signatures of basic biological organizing principles.