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Reliable Signal Transduction

ROY WOLLMAN, Dept of Chemistry and Biochemistry, University of California, San Diego

Stochasticity inherent to biochemical reactions (intrinsic noise) and variability in cellular states (extrinsic noise) degrade information transmitted through signaling networks. We analyzed the ability of temporal signal modulation - that is dynamics - to reduce noise-induced information loss. In the extracellular signal-regulated kinase (ERK), calcium (Ca(2+)), and nuclear factor kappa-B (NF-κB) pathways, response dynamics resulted in significantly greater information transmission capacities compared to nondynamic responses. Theoretical analysis demonstrated that signaling dynamics has a key role in overcoming extrinsic noise. Experimental measurements of information transmission in the ERK network under varying signal-to-noise levels confirmed our predictions and showed that signaling dynamics mitigate, and can potentially eliminate, extrinsic noise-induced information loss. By curbing the information-degrading effects of cell-to-cell variability, dynamic responses substantially increase the accuracy of biochemical signaling networks.