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Physical limits to concentration sensing in biochemical signaling[1]

NICHOLAS LICATA, SIMA SETAYESHGAR, Indiana University — In many biological systems, signals are carried by changes in the concentration of diffusable molecules which are transduced by receptors. It has been demonstrated experimentally that many signaling systems, from regulation of gene expression during development to bacterial chemotaxis, operate with remarkable sensitivity as indicated by a reliable response to small fractional changes in concentration. This sensitivity has contributions from an irreducible noise arising from the inherent random nature of the diffusing input signal, as well as from the chemical measurement process. By explicitly evaluating these theoretically derived contributions for the experimentally well- characterized bacterial chemotaxis network and motor response, we show that they are comparable to within factors of order unity, consistent with the observation that the measurement error approaches the physical lower limit set by diffusion. We extend our analysis to a class of ligand-gated ion channels, demonstrating the generality of this result where accuracy is especially important for the signaling system.

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