Response of the Hog1 MAPK Pathway in S. cerevisae Shows an Ability to Learn from Previous Stimulation

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In order to survive a wide range of osmotic conditions the budding yeast S. cerevisae has developed a combined signaling and genetic circuit that, under hypertonic shock, temporally up-regulates glycerol synthesis. In response to hyperosmotic stress, the MAPK Hog1 translocates to the nucleus upon phoshorylation by its upstream kinase Hence, nuclear localization of Hog1 is a direct measurement of activation of this protein cascade. Using YFP labeled Hog1 and RFP labeled nuclear protein Nrd1, the nuclear amount of Hog1 was tracked as a function of time. Cells were subjected to 250 mM pulses of NaCl for various periods from 4 minutes to 80 minutes. Simultaneous tracking of cell size gave a readout of the end product of the circuit as glycerol production increased and osmotic pressure equalized. Upon osmotic shock, initial Hog1 nuclear localization is transient, but subsequent identical shocks yielded an amplified response, and quicker size recovery. More frequent shocks, on a timescale shorter than adaptation, exposed previously hidden internal timescales as well as exhibit phase shifts with respect to the original stimulus. Additionally, we find that this circuit is almost purely a differential osmotic sensor. The ability of such protein circuits to learn from previous stimuli may be an important evolutionary tool for survival in diverse environmental conditions.