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Information flow and optimization in transcriptional regulation

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In the simplest view of transcriptional regulation, the expression of a gene is turned on or off by the changes in the concentration of a transcription factor (TF). Here we analyze transcriptional regulatory elements with the tools of information theory. Recent data on noise levels in gene expression are used to show that it should be possible to transmit much more than just one regulatory bit. Realizing this optimal information capacity would require that the dynamic range of TF concentrations used by the cell, the input/output relation of the regulatory module, and the noise levels of binding and transcription satisfy certain matching relations. This parameter-free prediction is in good agreement with recent experiments on the Bicoid/Hunchback system in the early Drosophila embryo, and this system achieves around 90% of its theoretical maximum information transmission. The dependence of information capacity on parameters that govern gene expression for simple, single-input / single-output, genetic regulatory elements is systematically examined and the extensions of the work to genetic circuits consisting of several interacting elements are presented.