Generation and Synchronization of Oscillations in Synthetic Gene Networks

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In this talk, I will describe our recent experimental and theoretical work on small synthetic gene networks exhibiting oscillatory behavior. Most living organisms use internal genetic "clocks" to govern fundamental cellular behavior. While the gene networks that produce oscillatory expression signals are typically quite complicated, certain recurring network motifs are often found at the core of these biological clocks. One common motif which may lead to oscillations is delayed auto-repression. We constructed a synthetic two-gene oscillator based on this design principle, and observed robust and tunable oscillations in bacteria. Computational modeling and theoretical analysis show that the key mechanism of oscillations is a small delay in the negative feedback loop. In a strongly nonlinear regime, this time delay can lead to long-period oscillations that can be characterized by ``degrade and fire" dynamics. We also demonstrated synchronization of synthetic gene oscillators across cell population as well as multiple populations using variants of the same design in which oscillators are synchronized by chemical signals diffusing through cell membranes and throughout the populations.