ASU Department of Physics
Arizona State University

COLLOQUIUM

Thursday, November 9, 2023

Refreshments at 3:15pm outside PSF 101
Colloquium from 3:30pm - 4:30pm in PSF 101

Pattern Recognition by Molecular Self-Assembly

Professor Erik Winfree

Caltech

Abstract:

Inspired by biology's most sophisticated computer, the brain, neural networks constitute a profound reformulation of computational principles. Remarkably, analogous high-dimensional, highly-interconnected computational architectures also arise within information-processing molecular systems inside living cells, such as signal transduction cascades and genetic regulatory networks. Might collective modes analogous to neural computation be found more broadly in other physical and chemical processes, even those that ostensibly play non-information-processing roles? Here we examine nucleation during self-assembly of multicomponent structures, showing that high-dimensional patterns of concentrations can be discriminated and classified in a manner similar to neural network computation. Specifically, we design a set of 917 DNA tiles that can self-assemble in three alternative ways such that competitive nucleation depends sensitively on the extent of colocalization of high-concentration tiles within the three structures. The system was trained in-silico to classify a set of 18 grayscale 30×30 pixel images into three categories. Experimentally, fluorescence and atomic force microscopy measurements during and after a 150-hour anneal established that all trained images were correctly classified, while a test set of image variations probed the robustness of the results. While slow compared to prior biochemical neural networks, our approach is surprisingly compact, robust, and scalable. Our findings suggest that ubiquitous physical phenomena, such as nucleation, may hold powerful information processing capabilities when they occur within high-dimensional multicomponent systems.
Joint work with Constantine Evans, Jackson O'Brien, and Arvind Murugan.

Biography:

Erik Winfree graduated with a B.S. in Mathematics, with a specialization in Computer Science, from the University of Chicago in 1991. Under the supervision of John Hopfield — and with considerable input from Len Adleman, Ned Seeman, Paul Rothemund, and Sam Roweis — he earned his Ph.D. in Computation & Neural Systems from Caltech in 1998. After postdoctoral research at Princeton in Stan Leibler's group and a period as a visiting scientist in Tom Knight's group at MIT, he joined the faculty at Caltech in 2000, where he is now Professor of Computer Science, Computation & Neural Systems and Bioengineering. Winfree's theoretical and experimental research examines chemistry as an information technology, making use of DNA nanotechnology and cell-free synthetic biology to develop a systematic approach to molecular programming with a sound theoretical foundation. Winfree currently leads the DNA and Natural Algorithms group at Caltech. He was inducted as a Fellow of the AAAS (2015), received the Feynman Prize for Nanotechnology (2006), a MacArthur Fellowship (2000), and the Rozenberg Tulip Prize in DNA Computing (2000).

Host: Prof. Rizal Hariadi
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