

BioComputation

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DARPA/ITO



Problem

- **Biotechnology has advanced dramatically over the past two decades**
- **This has two important implications:**
 - **the barrier to entry for misusing the technology has been lowered**
 - **potential for constructing designer biological agents for use in asymmetric warfare or terrorist activities**
 - **opportunities exist to leverage work in biological sciences to drive innovation in computer science and engineering**

Background

- **BioSPICE: a simulation environment that enables the rapid exploration and analysis of intracellular processes**
 - computational modeling of well-conserved biological mechanisms
 - creation of an infrastructure that brings to bear a wide range of genomic, proteomic, and molecular data
- **DNA Computing**
 - exploit biomolecules as engineering elements
 - computation
 - design of novel sensors
 - self-assembly of physical nano-structures

Objectives

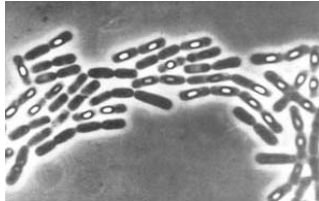
- **To identify new research in the biological sciences that will impact BioSPICE development**
 - genomic, proteomic, and cell biology research
 - long oligonucleotide synthesis
- **To assess the BioSPICE architecture**
 - database interoperability
 - modeling and simulation techniques
- **To identify new applications of biomolecules in the domains of computer science and engineering**

Activities

- **MITRE is performing assessments on a number of key research areas**
 - cell-cycle regulation
 - stem cells
 - immunology
- **Identifying areas appropriate for theoretical analysis and computational modeling**
 - emergence of systems biology
 - *quantitative* and predictive models of cellular processes
- **Facilitating interactions with industry leaders and other government agencies**

Highlight

Model organism(s)



Bacillus subtilis
(anthrax simulant)

Data on proteins and gene networks involved in intracellular processes

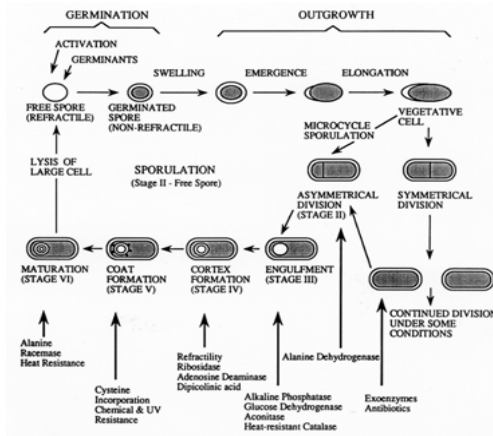


Figure and circuit from Dr. Adam Arkin, UC Berkeley

Mathematical models to predict responses

$$\frac{dA}{dt} = -\frac{k_b B_p A}{K_B + A} + \frac{k_r R(A_0 - A)}{K_R + (A_0 - A)}$$

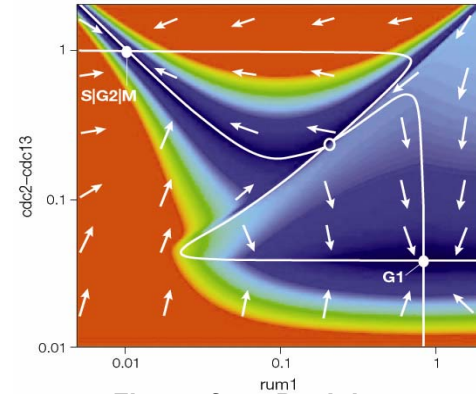


Figure from Dr. John Tyson, Virginia Tech.

Computational modeling of biological processes

Highlight



DNA used to perform computation

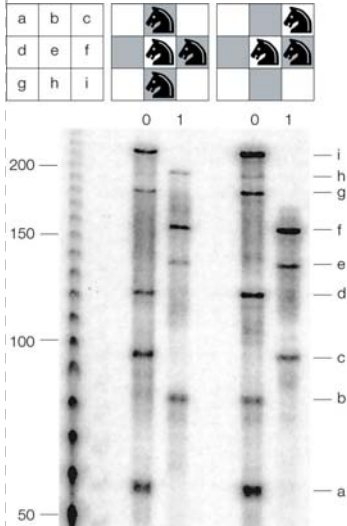


Figure from Dr. Laura Landweber, Princeton University

DNA self-assembles into a programmed physical structure

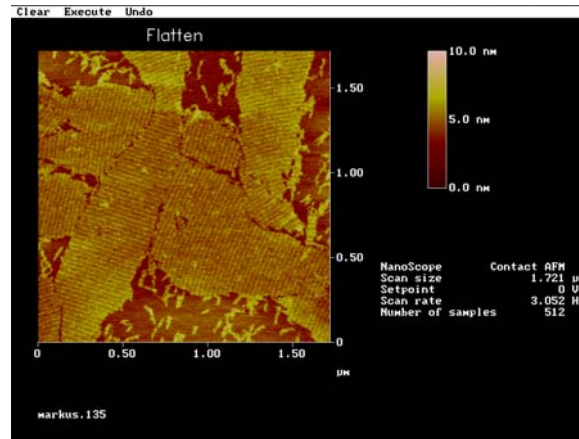


Figure from Dr. Nadrian Seeman, New York University

Hybrid bio-nano devices: radio control of DNA and proteins

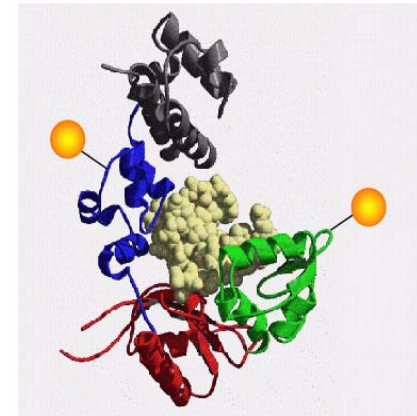


Figure from Dr. Joseph Jacobson, MIT Media Labs

Biomolecules as a computational substrate

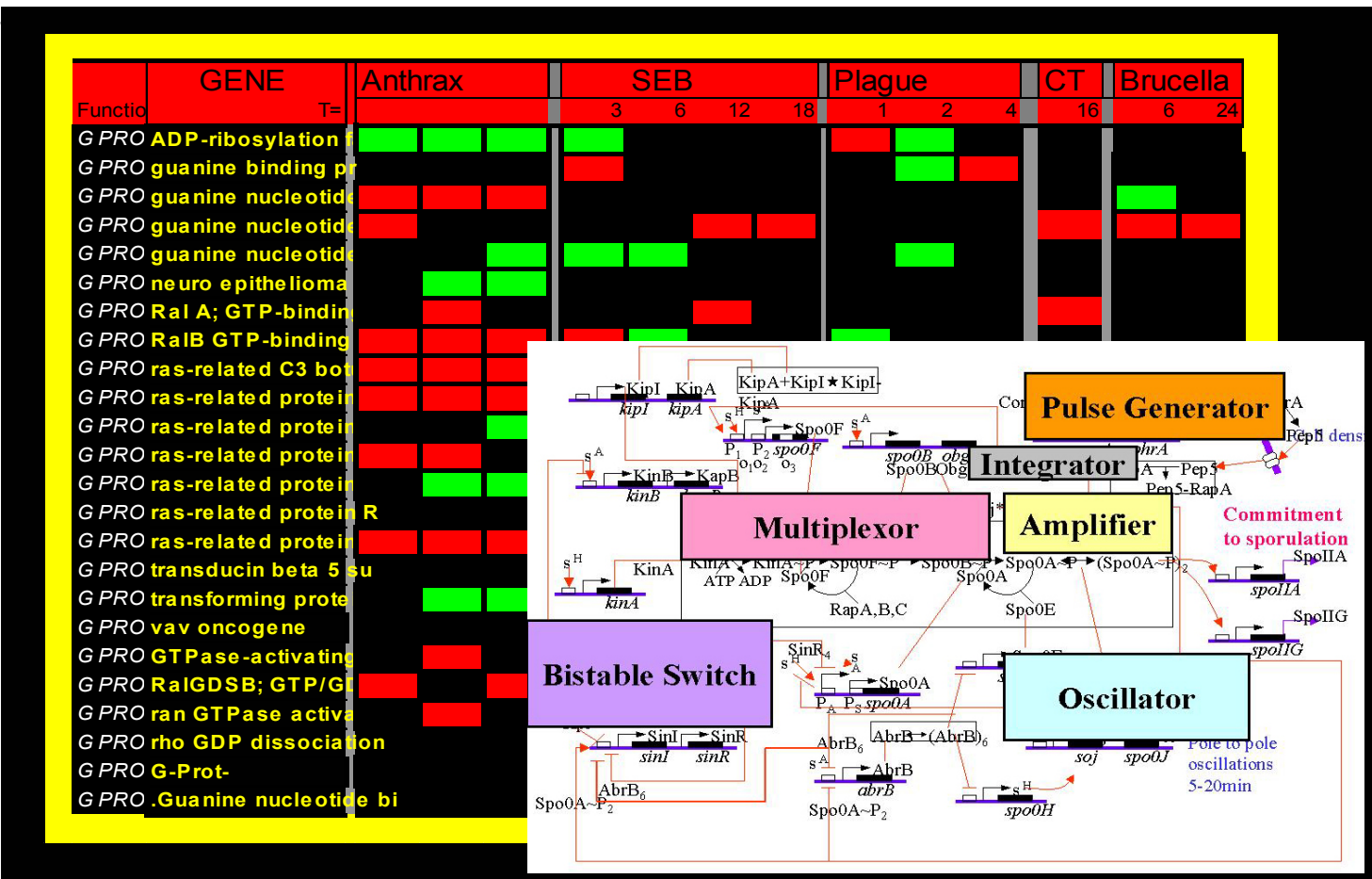


Impacts

- **MITRE is supporting DARPA in the creation of BioSPICE: an infrastructure that will enable biology researchers to rapidly simulate intracellular processes**
 - quickly refine hypotheses about how a new biological agent or pathogen is acting
 - design and test *in silico* alternative intervention strategy

- **MITRE has cultivated strong interest from industry leaders and other government agencies**

Future Plans



Background figure from Dr. Marti Jett, Walter Reed Army Institute of Research; inset from Dr. Adam Arkin, UC Berkeley