Programming Biological Cells

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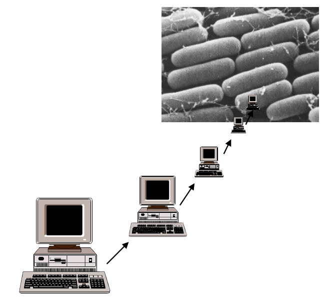
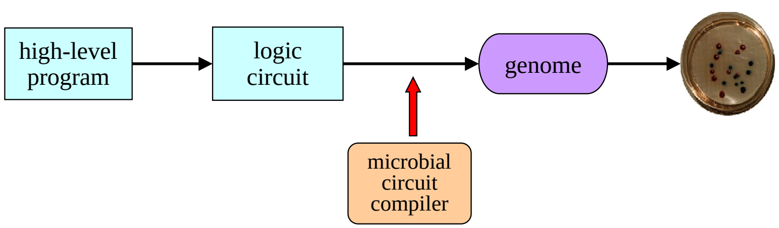
Motivation

- Goal: program biological cells
- Characteristics
  - small (***E.coli***: 1x2µm , 10^9/ml)
  - self replicating
  - energy efficient
- Potential applications
  - "smart" drugs / medicine
  - agriculture
  - embedded systems



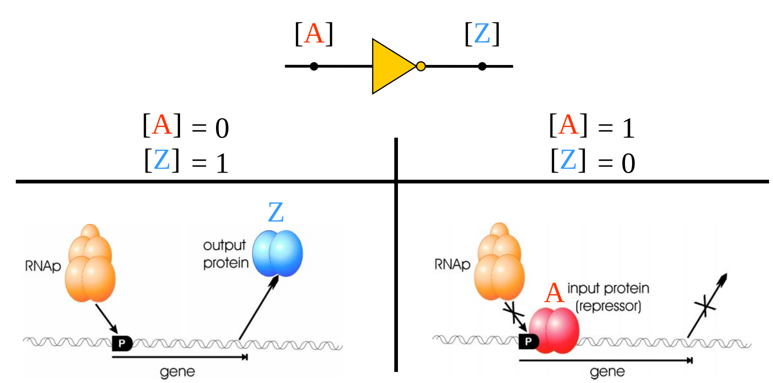
Approach



Outline:
- Building biological digital circuits
  - compute, connect gates, store values
- High-level programming issues

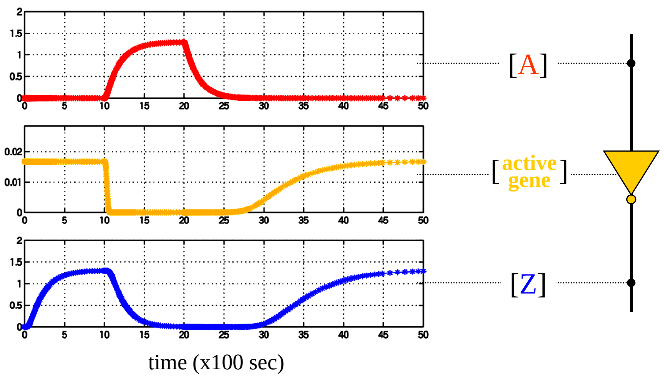
Compute: Biological Inverter

- signal = protein concentration level
- computation = protein production + decay



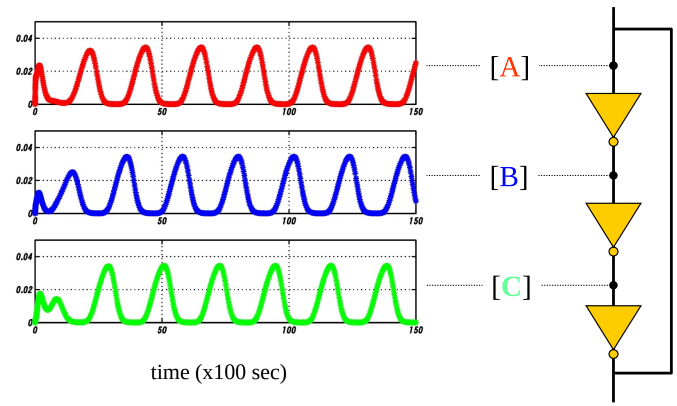
Inverter Behavior

- Simulation model based on λ phage biochemistry

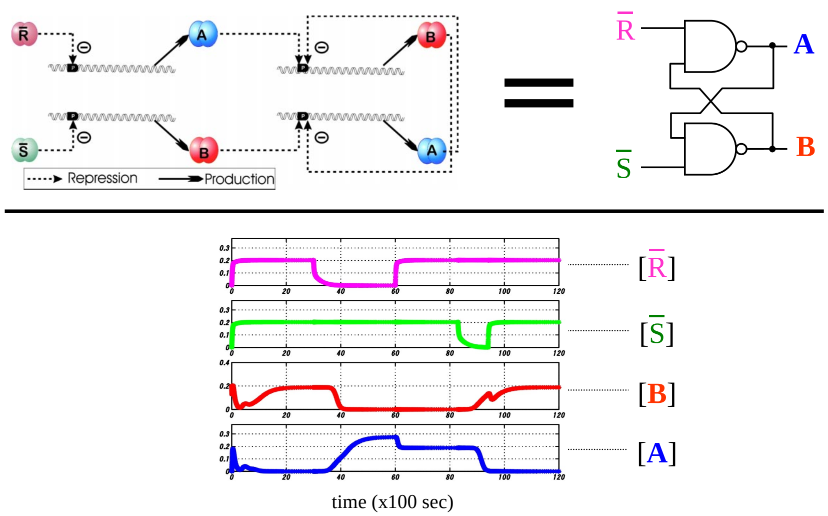


Connect: Ring Oscillator

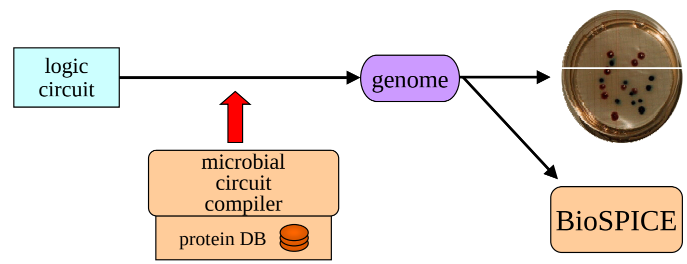
- Connected gates show oscillation, phase shift



Memory: RS Latch



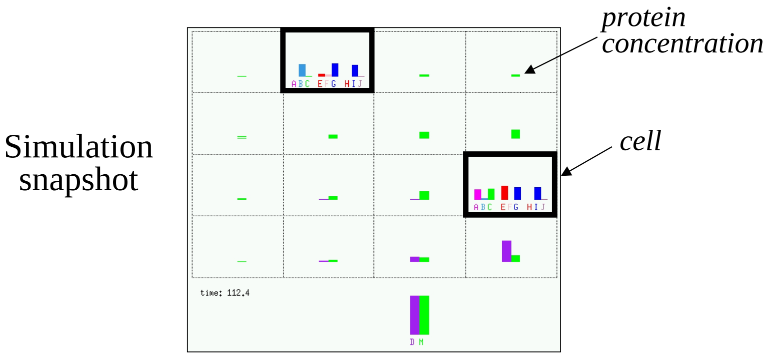
Microbial Circuit Design



- Assigning proteins is hard.
- BioSPICE: Simulate a colony of cells

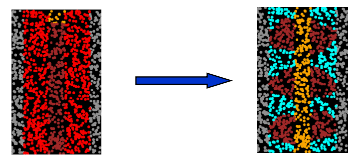
BioSPICE

- Prototype protein level simulator
  - intracellular circuits, intercellular communication



High Level Programming

- Requires a new paradigm
  - colonies are amorphous
  - cells multiply & die often
  - expose mechanisms cells can perform reliably
- Microbial programming language
  - example: pattern generation using aggregated behavior



Conclusions + Future Work

- Biological digital gates are plausible
- Now:
  - Implement digital gates in *E. coli*
- Also:
  - Analyze robustness/sensitivity of gates
  - Construct a protein kinetics database
  - Study protein↔protein interactions for faster logic circuits