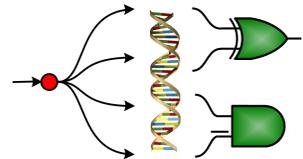


Biological Computation via DNA Strand Displacement



CIRCUITS & BIOLOGY
University of Minnesota



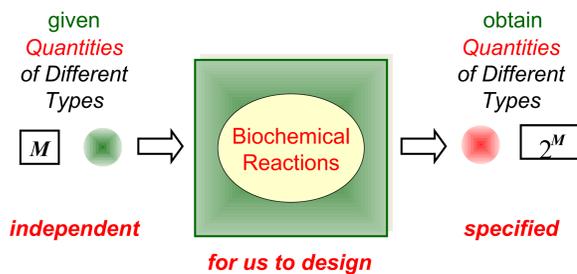
Aleksandra P. Vedeneva
Undergraduate
Electrical and Computer Engineering
University of Minnesota
veden002@umn.edu

Marc D. Riedel
Assistant Professor
Electrical and Computer Engineering;
Graduate Faculty
Biomedical Informatics and Computational Biology;
University of Minnesota
mriedel@umn.edu

Hua Jiang
Graduate Student
Electrical and Computer Engineering
University of Minnesota
hua@umn.edu

Keshab Parhi
Professor
Electrical and Computer Engineering;
University of Minnesota
parhi@umn.edu

Synthesizing Biological Computation



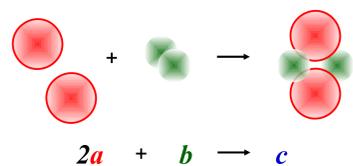
Design a system that computes *output* quantities as *functions* of *input* quantities.

Functional Dependencies

Exponentiation	$N = 2^M$
Logarithm	$N = \log_2(M)$
Linear	$N = \alpha M$
Raising-to-a-Power	$N = M^P$

Basic Computational Mechanism

A biochemical reaction:

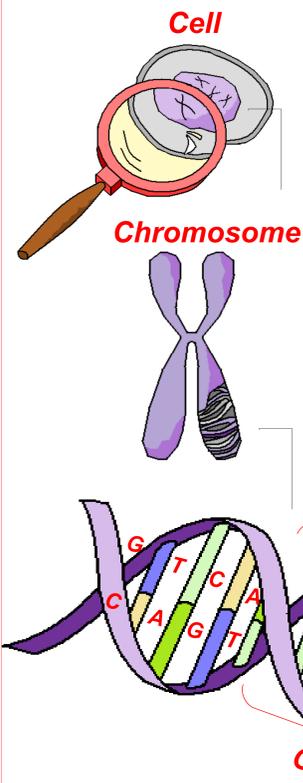
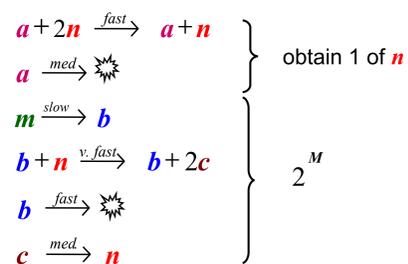


rule specifying how types of molecules combine.

Example: Exponentiation

Start with M of type m . Produce 2^M of type n .

Use working types a, b, c .



From Cell to DNA Level

Nucleus is a part of the cell that contains most of the cell's genetic material

Chromosome is a very long DNA molecule and associated proteins (humans have 23 pairs of chromosomes).

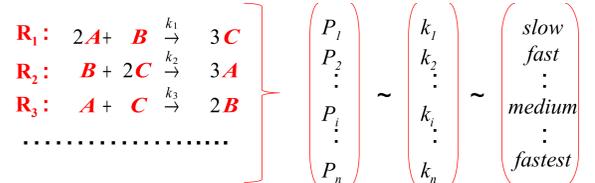
Deoxyribonucleic acid (DNA) is a nucleic acid present in the cells of all living organisms. The nucleotides which make up DNA are adenine (A), thymine (T), cytosine (C), and guanine (G)

Base pairs are two nucleotides on opposite complementary DNA strands (A and T, G and C)

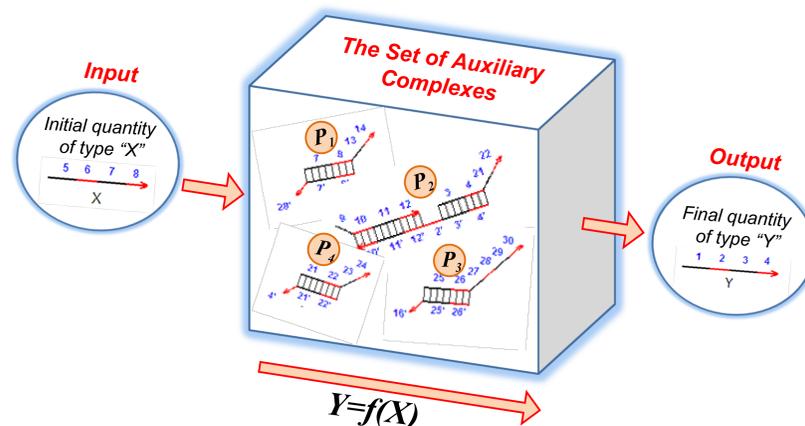
Gene is as a region of DNA that controls a hereditary characteristic (can be as short as 1000 base pairs or as long as several hundred thousand base pairs)

Probability of DNA Strand Displacement Reactions

The *probability* P_i that a given reaction R_i is the next to fire is proportional to its *rate* k_i

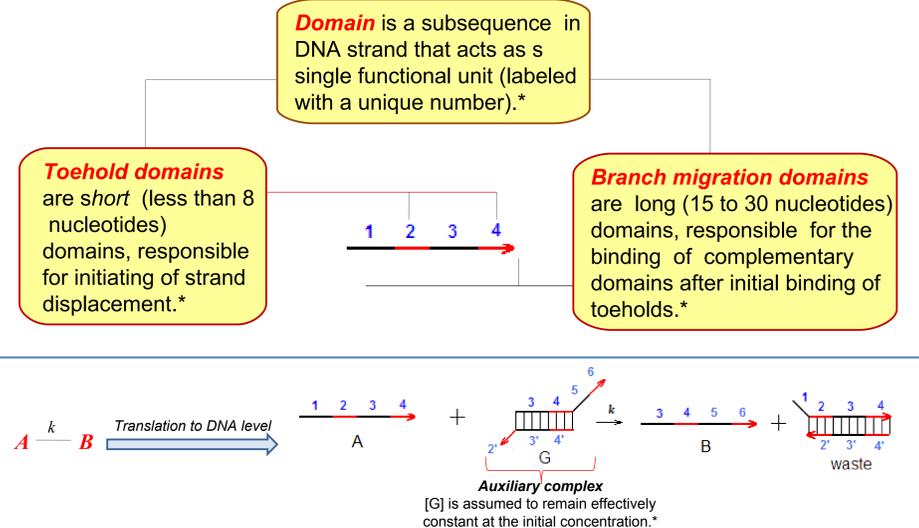


On the DNA level the reaction rate constant is controlled by *the length and sequence composition of the toehold*.*

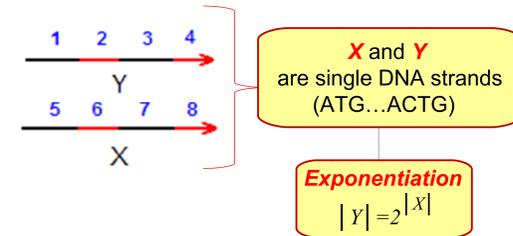


Translation Biochemical Reactions into DNA Strand Displacement Reactions

"Strand displacement" is a shorthand for toehold-mediated branch migration and strand displacement reactions, combined with the principles of toehold sequestering, and toehold exchange.*



Representation of Exponentiation as Strand Displacement Reactions



* Based on research from "DNA as a universal substrate for chemical kinetics" by David Soloveichik, Georg Seelig, and Erik Winfree.

