What We've Achieved

Created a design tool: a **library** of toeholds with different reaction speeds

Simulated **3675** DNA toehold sequences

Experimentally verified the reaction speed of **10** different toehold designs

Created a **website** through which researchers can access our library

Why It Matters

By enabling designers to select DNA sequences with predictable reaction speeds, our library supports the development of:

- Programmable chemical reaction networks
- More reliable DNA-based logic switches
- Smarter drug delivery systems
- Sensitive and adaptable biosensors

Want to Learn More?

Scan the QR Code to find our full report, web-based tool, & full references!

Find Us

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DYNAMICS BY DESIGN

Designing a Library of DNA Parts to Control the Reaction Speed of DNA Systems

IMPERIAL

Developed by:
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Motivation

Molecular circuits built from **DNA** can operate where electronics cannot — such as inside living organisms!

To control the output of these systems we need to know **how** DNA molecules will interact and **how fast** they will do so.

DNA interactions are well-understood, but if engineers could better control the **rate** at which their systems evolved, this could revolutionise the nanotechnology landscape.

Goals

Develop a tool to enable researchers to design DNA-based circuits with **specific reaction rates** spanning several orders of magnitude.

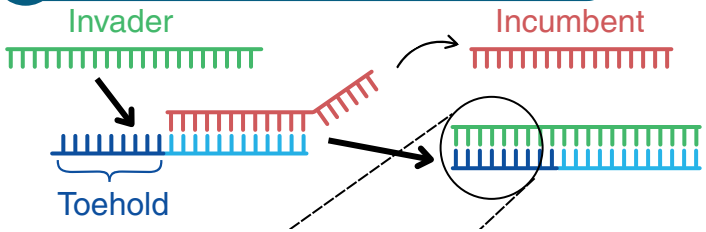
Specifically, we aimed to:

- **Design a tool** to control the reaction speed of DNA-based systems
- **Experimentally verify** our proposed tool's performance
- Create a platform which allows **easy access** to our tool

Building Our Idea

Many DNA circuits rely on a type of reaction known as **strand displacement**.

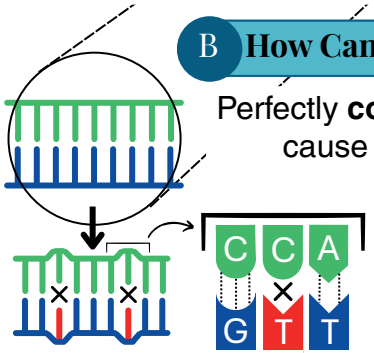
A What is DNA Strand Displacement?



An invader strand binds the **toehold** region of a DNA complex and pushes out the **incumbent** strand, which can trigger other reactions.

B How Can We Change the Speed?

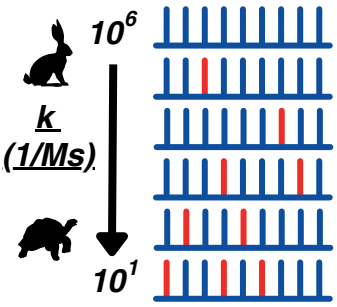
Perfectly **complementary** toeholds cause **fast** displacement.



Nucleotide **mismatches** in the toehold weaken binding and **slow** the reaction.

C Our Concept: A Toehold Library

By changing the **number** and **position** of toehold mismatches, we can achieve **almost any** rate constant, ***k***.

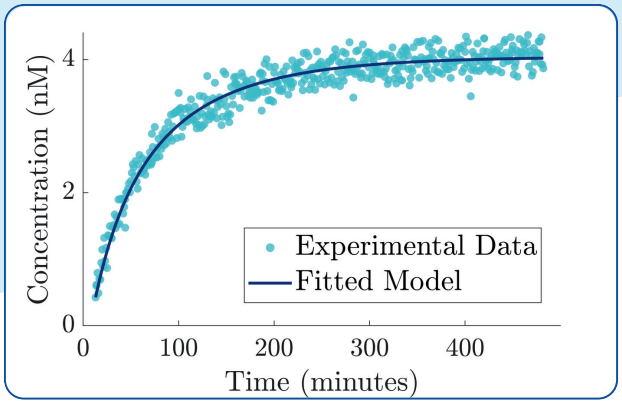


Building on this concept, we designed and simulated a **library** of **toehold** designs and their associated **reaction rates**.

Testing Our Concept

We conducted strand displacement reactions using **several** toeholds from our library to test if our simulated reaction rates were accurate.

The progression of **each** reaction was tracked by plotting the concentration of the **incumbent** strand over time.



We fit a mathematical model to our data to recover the rate constant, ***k***, for each toehold and verify it was as expected.

Expanding Our Platform

We built a website which takes in a **desired rate constant**, and outputs an **optimised toehold** sequence.