Foundation of IT 1947

Foundation of Bioengineering 1953
DNA is a programming language for biochemistry (metabolism).

It can also specify how to build hardware.

Nature supports incredible diversity – over 2 million species we can see!
1980
500 bp/day (manual)

1987
36,000 bp/day (semi-auto)

1995
144,000 bp/day (semi-auto)

1998
500,000 bp/day (automatic)

2007 – Sequencing by Synthesis
1GB bp/day (automatic)
Environmental Shotgun Sequencing: Its Potential and Challenges for Studying the Hidden World of Microbes
IBM’s BlueGene/L: world’s fastest supercomputer, 3 years running

596 TFLOPS (trillion floating point operations per second)
The problem with reverse engineering…

REDUCTION | COMPLEXITY

If we didn’t build it, we may not be able to fully understand it.
Towards “forward” bio-engineering
Over 3500 RE’s available

Restriction Enzyme
Action of EcoRI
if you can WRITE DNA,

you're no longer LIMITED to "what IS" but to what you could MAKE.
Gene Synthesis $0.59/bp
Dependable Service @ Low Price: Come on Down and Save Your Budgets!
www.epochbiolabs.com

Blue Heron Gene Synthesis
Gene Synthesis - Explore the possibilities! Save Time & Budget
www.blueheronbio.com

Bio S&T Gene Synthesis
Low price, free LB stab and bonus DNA ladder.
www.biost.com

Custom Gene Synthesis
For small, large & difficult genes. Free codon optimization services
www.celtek-genes.com

Custom Gene Synthesis
What if you could engineer any gene to speed up R&D? Build with us.
www.codondevices.com

1/27/2008
Applications dependent on synthetic capabilities and $\text{base pairs}$

- Single genes
- Minimal life

Genetic circuits, viruses, GEMs

Engineered organisms

10^2 \quad 10^3 \quad 10^4 \quad 10^5 \quad 10^6 \quad 10^7
100 Million letters of care packages every 24 hours
### Transcriptional Regulators

#### Available repressible regulators (normally ON)

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Direction</th>
<th>Control</th>
<th>Output Low High</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBa_J14032</td>
<td>promoter P(Lac)IQ</td>
<td>Forward</td>
<td>aTc, tetracyline</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>BBa_R0040</td>
<td>promoter (tetR, repressive)</td>
<td>Forward</td>
<td></td>
<td></td>
<td>54</td>
</tr>
<tr>
<td>BBa_R0051</td>
<td>promoter (lambda cl regulated)</td>
<td>Forward</td>
<td></td>
<td></td>
<td>49</td>
</tr>
</tbody>
</table>

#### Available inducible regulators (normally OFF)

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Direction</th>
<th>Control</th>
<th>Output Low High</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBa_J12007</td>
<td>Modified lambda Prm promoter (OR-3 obliterated)</td>
<td>Forward</td>
<td>cl</td>
<td></td>
<td>62</td>
</tr>
<tr>
<td>BBa_R0062</td>
<td>Promoter (LuxR &amp; HSL regulated ...luxPR)</td>
<td>Forward</td>
<td>LuxR, HSL</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>BBa_R0079</td>
<td>Promoter (LasR &amp; PAI regulated)</td>
<td>Forward</td>
<td>PAI</td>
<td></td>
<td>157</td>
</tr>
<tr>
<td>BBa_R0080</td>
<td>Promoter (AraC regulated)</td>
<td>Forward</td>
<td>araC</td>
<td></td>
<td>149</td>
</tr>
</tbody>
</table>

#### Available other regulators

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Direction</th>
<th>Control</th>
<th>Output Low High</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBa_J0500</td>
<td>Inducible pBAD/araC</td>
<td>Forward</td>
<td>araC, arabinose</td>
<td></td>
<td>1210</td>
</tr>
<tr>
<td>BBa_J13453</td>
<td>Phad promoter</td>
<td>Forward</td>
<td></td>
<td></td>
<td>130</td>
</tr>
<tr>
<td>BBa_J13002</td>
<td>TetR repressed POPs/RIPS generator</td>
<td>Forward</td>
<td>ATc</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td>BBa_J13023</td>
<td>3OC12HSL-LuxR dependent POPs/RIPS generator</td>
<td>Forward</td>
<td></td>
<td></td>
<td>117</td>
</tr>
<tr>
<td>BBa_J23101</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23102</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23103</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23104</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23105</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23106</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23107</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23108</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23109</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23110</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>BBa_J23111</td>
<td>constitutive promoter family member</td>
<td>Forward</td>
<td></td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

[http://parts.mit.edu](http://parts.mit.edu)
BBa_F2620
3OC_6HSL → PoPS Receiver

Description
A transcription factor (LuxR, BBa_C0062) that is active in the presence of cell-cell signaling molecule 3OC_6HSL is controlled by a TetR-regulated operator (BBa_R0040). Device input is 3OC_6HSL. Device output is PoPS from a LuxR-regulated operator. If used in a cell containing TetR then a second input signal such as αC can be used to produce a Boolean AND function.

Characteristics
- **Input Swing:** 1E-9 to 1E-6 M 3OC_6HSL, exogenous
- **Output Swing:** 0s1 to 50s3.1 GFP molecules cm⁻³ s⁻¹
- **Switch Point:** 7s1 nM 3OC_6HSL, exogenous
- **LH Response:** 9 min (f₀₀₀₀), 27 min (f₀₀₀₀)

Key Parts
- BBa_R0040: TetR-regulated operator
- BBa_C0062: luxR ORF
- BBa_R0062: LuxR-regulated operator

Response Time*

Stability**

Registry of Standard Biological Parts
making life better, one part at a time

License: Public
Synthetic biology requires an unprecedented level of interdisciplinary cooperation, fewer laboratory skills, and less overhead than conventional genetic engineering.
iGEM 2007 is now officially concluded! Congratulations to all!

- Results
- See the medal winners
- Media (including links to videos and flickr photo gallery)
- Learn about iGEM 2008

Results of the Jamboree

Cambridge & Melbourne Leap Together
Cambridge University & Melbourne University leap together after co-winning the Best BioBrick Part award.
indole deficient tnaA5^- chassis

- chorismate → SAGD → salicylic acid → osmY → WGD
- leucine → IAGD → 3-methylbutanal → isoamyl alcohol → osmY → BSGD

methyl salicylate

isoamyl acetate

banana

NADH → NAD^+
Under a magnification of 65,000, this scanning electron micrograph (SEM) depicts a number of Escherichia coli bacteria of the strain 0157:H7.

(Courtesy of Center for Disease Control and Prevention)

Sci-Tech

Alberta team trying to turn E. coli into fuel
Updated Mon. Nov. 5 2007 6:15 AM ET

The Canadian Press

CAMBRIDGE, Mass. -- A University of Alberta team trying to turn E. coli into fuel has earned a first-place finish in the energy category at an international genetic engineering competition at MIT.

Andrew Hessels, a consultant with the Alberta Ingenuity Fund who has helped teams from three Alberta universities compete, says while none of the teams from the University of Calgary, the University of Lethbridge or the U of A made it to the final competition, he calls it a fantastic educational experience.
Genetic-Engineering Competitors Create Modular DNA Dev Kit

By Alexis Madrigal  11.13.07 | 7:30 PM

College and high school students are helping MIT scientists develop an open source development kit for biological systems that could do for cells what Linux has done for computers.

As part of the International Genetically Engineered Machines competition held in Cambridge, Massachusetts, last week, Peking University students created tiny assembly lines out of bacteria. Their entry, "Towards a Self-Differentiated Bacterial Assembly Line," won them the grand prize among 50 teams from around the world.

"Biology is going to be able to make the things that we want," said Tom Knight, an MIT engineer and co-founder of iGEM. "And when that happens, the economics of production are going to change dramatically. It doesn't take a billion-dollar [facility] to make stuff. It takes a hundred-dollar incubator."

The Top 10 New Organisms of 2007
English, Algebra, Phys Ed ... and Biotech

George Cachianes, left, formerly of Genentech, teaches biotechnology at Lincoln High School in San Francisco.
BERKELEY CENTER FOR SYNTHETIC BIOLOGY

A joint program of the California Institute for Quantitative Biomedical Research (QB3) and Lawrence Berkeley National Laboratory (LBNL)

The California Institute for Quantitative Biomedical Research (QB3) and Lawrence Berkeley National Laboratory (LBNL) have joined forces to accelerate the growth of synthetic biology, a new field that promises major new advances in preventing and treating disease, generating new energy sources, and preventing and mitigating environmental threats.

Opening in spring 2005 in a spacious, modern building in west Berkeley, the Berkeley Center for Synthetic Biology gives renowned scientists and engineers the chance to pool their talents and collaborate in new ways, with enormous potential benefits for California’s citizens in the form of advances in biomedicine and energy renewables and economic growth.

Synthetic biologists study the control and design of biological components and new organisms to solve a host of important health, energy, and environmental problems that cannot be solved using naturally occurring biological entities. The inherently

MIT establishes groundbreaking biological engineering major

February 17, 2005

The Massachusetts Institute of Technology faculty yesterday approved a new course of study for undergraduates, in biological engineering, the first entirely new curriculum established at the Institute in 29 years.
TIME
COMPUTER GENERATION
A New Breed of Whiz Kids
MAY 3, 1982
$1.50
1.3%
INFLATION VANISHES!
At Least for A Month
THAT'S RIGHT, ALEC! SCRIPT IT IS A WORD PROCESSING PROGRAM. MY DAD HAS A TRS-80 MODEL I COMPUTER WITH SCRIPT IT IN HIS OFFICE... AND HE TAUGHT ME HOW TO USE IT WITH A DIXIE WHEEL PRINTER...

SCRIPIT WORD PROCESSING WORKS IN OUR SCHOOL'S OFFICE...

AFTER THAT THE WORD "INITIALIZING" APPEARS WHICH MEANS THE COMPUTER IS LOADING THE PROGRAM...

... AND SO ON AND SO ON...

NEXT, THE COMPUTER PROMPTS YOU TO ENTER THE YEAR USING THE 24-HOUR SYSTEM, GIVING HOURS, MINUTES, AND SECONDS:

FOR EXAMPLE:

APRIL 6, 1984... Type 04/06/84, and then press the enter key.

“AND IN TURN, A DOCUMENT CAN BE MADE UP OF SEVERAL PAGES OF INFORMATION...”
ADVENTURES IN SYNTHETIC BIOLOGY

STORY: DREW ENDY  ISADORA DEESEE
THE MIT SYNTHETIC BIOLOGY WORKING GROUP
ART: CHUCK WADEY  WWW.CHUCKWADEY.COM

ENGINEERED GENETIC DEVICES

I KNOW BACTERIAL BALLOONS COULD WORK.
IF ONLY THERE WAS SOME WAY TO STOP THEM FROM BROWSING UNTIL THEY EXPLODE!

OK, PAY ATTENTION! AN INVERTER IS A COMBINATION OF BASIC DNA PARTS THAT-

1. Ribosome Binding Site (RBS) - Basic elements that start the process of protein synthesis.
2. Repressor - A gene that encodes a particular type of protein that will bind DNA sites in a specific regulatory area and cause changes in the rate of gene expression.
3. Termination - Special elements that decrease the flow of RNA polymerase along DNA, sometimes to zero.
4. Operator - Sections of DNA that contain sequences precisely blocking RNA polymerase binding and initiation sites. With a Repressor protein, the Operator part will be turned OFF. Without a Repressor protein, the Operator part will be turned ON, allowing RNA polymerase to bind and initiate a HIGH output right.

IT COULD BE THE ANSWER YOU'RE LOOKING FOR.

SEE, THANKS FOR TELLING ME AHEAD OF TIME!

WHAT THE HELL IS AN INVERTER?

YOU COULD HAVE USED AN INVERTER DEVICE TO HELP PREVENT BUDDY'S UNFORTUNATE ACCIDENT.

ERGH...

YOU DON'T HAVE TO RUB IT IN.

UM... WHY'S IT CALLED A REPRESSOR?

IT'S ENOUGH YOU'RE A KNOW-HOW, ALL YOU DON'T HAVE TO RUB IT IN.

WE CALL AN INVERTER A DEVICE IN ORDER TO HIDE ALL THE DETAILS OF HOW IT WORKS.

NOW YOU TELL ME WHAT IT DOES.

DON'T FEEL BAD. MY POINT IS, YOU SHOULDN'T HAVE TO MEMORIZE EVERY LAST PIECE OF DNA.

I HAVE NO IDEA. OK? WHAT IS IT?

WE'RE GOING TO HIDE ALL THESE DETAILS INSIDE THE DEVICE.

HOW DID YOU DO THAT?
Projects with DNA
For ages 8 and up
Adult Supervision Required
Materials included except for the items listed.
Through play, hands-on projects, patterns and puzzles
this book and kit explores the amazing DNA story.

Build a DNA ladder.
Extract DNA
Heat SHOCK!
Decide the code of life
Grow glowing cells

Ooey, Gooey, DNA!
Dress up for sterile techniques.
Quality time, quality learning, quality play.

Is it a boy or girl?
Solve the chromosome puzzle.
Why do bioengineering?

• Any chemical process can be done with biochemistry – no need for harsh chemical conditions, temperature, etc.
• Runs on sugar or sunlight
• Bio-compatible and biodegradable
• Self-reproducing > very low cost
• Potentials are virtually untapped
• Evidence suggests many of today’s engineering activities will begin to move towards bioengineered processes > big economic shift on the order of computing
• Life and life processes are important – should be widely used and understood, not in the hands of a few elites – hence the need for “open source biology”
• Registration fees ($1000/team)
• Teach the teachers meeting (MIT, May)
• Regional meetings and seminars
• Travel and accommodation for up to 100 students to MIT Jamboree in November
• $5,000 research start-up fees
• Support, technical advice, media relations