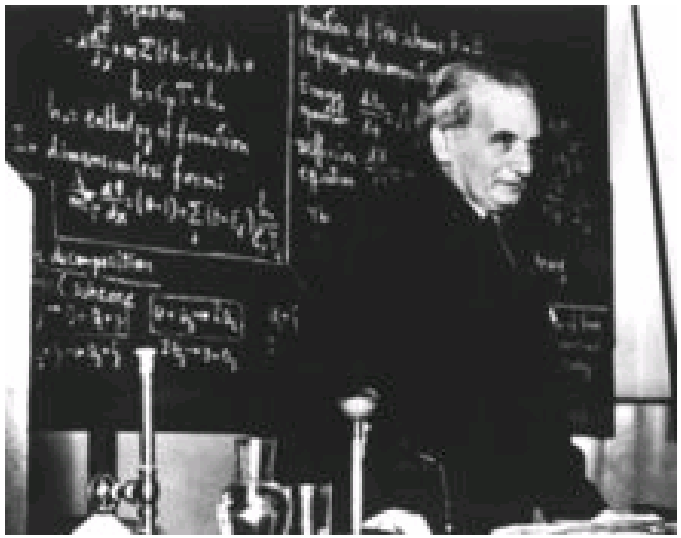
# Synthetic Biology

Andrew Hessel
July 4 2007
ahessel@gmail.com



*A Scientist discovers that which exists; an Engineer creates that which never was.*

-- Theodore Von Kármán

“**Synthetic biology** is an emerging area of research that can broadly be described as the design and construction of novel artificial biological pathways, organisms or devices, or the redesign of existing natural biological systems.”

# Technology of synthetic biology

It’s all about DNA…

DNA is the machine language program for biochemical processes

The ability to manipulate this one molecule allows virtually anything biological to be engineered!

DNA is to biology as the electron is to computing


danielg 072006 - S3is

# Reading code

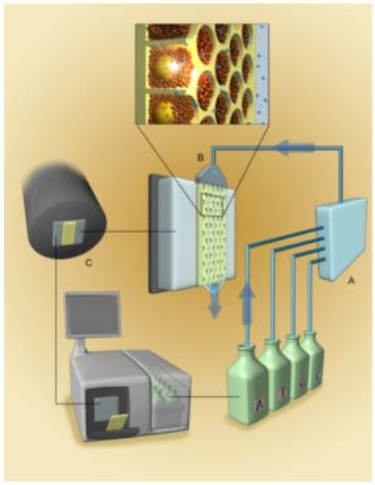
Nobel foundation

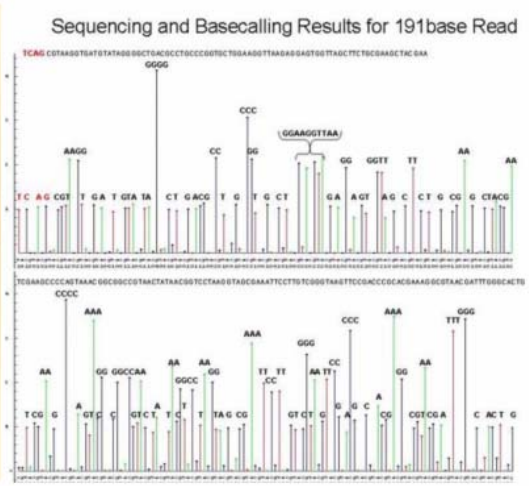
1980
500 bp/day (manual)

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

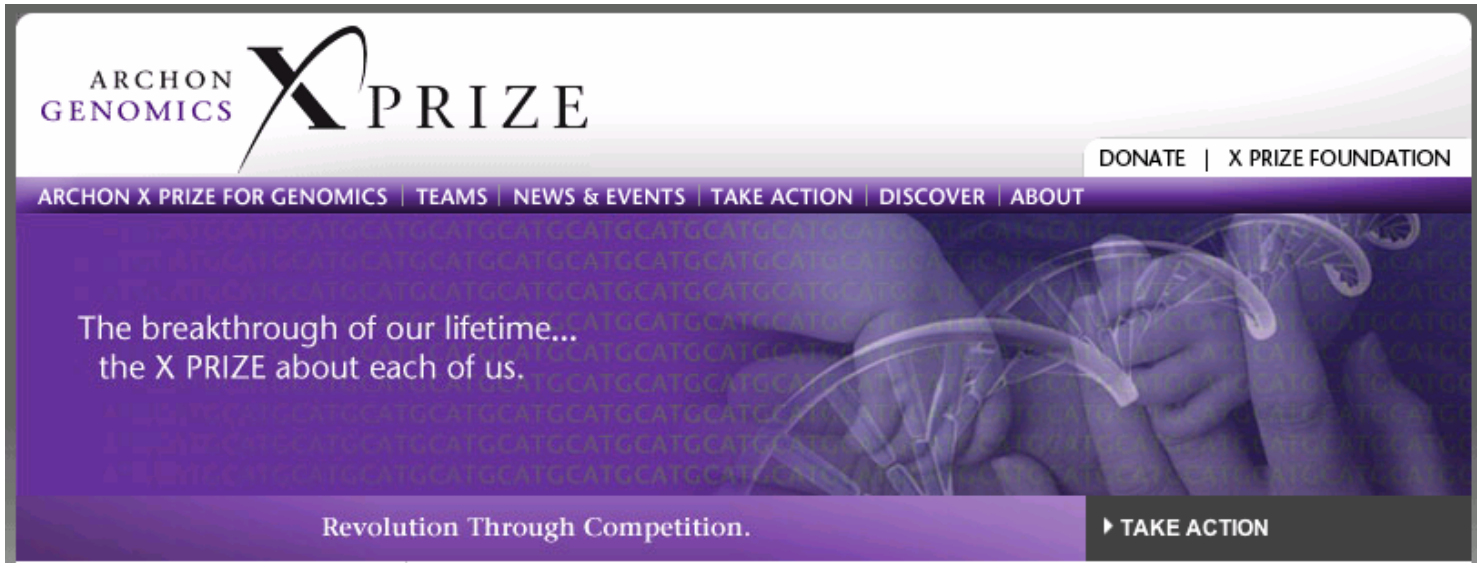
1995
144,000 bp/day (semi-auto)

1998
500,000 bp/day (automatic)






2007 – Sequencing by Synthesis
1GB bp/day (automatic)


ARCHON GENOMICS X PRIZE
DONATE | X PRIZE FOUNDATION
ARCHON X PRIZE FOR GENOMICS | TEAMS | NEWS & EVENTS | TAKE ACTION | DISCOVER | ABOUT
The breakthrough of our lifetime...
the X PRIZE about each of us.
Revolution Through Competition.
TAKE ACTION

# Comprehension

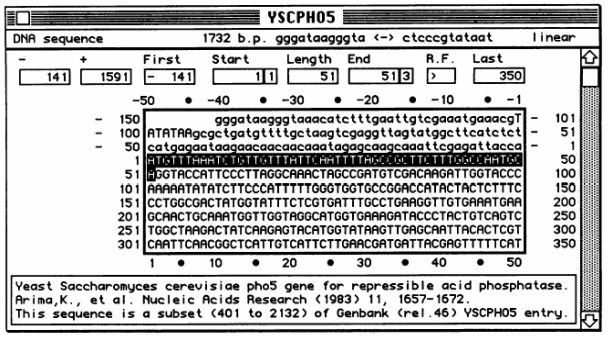

Volume 16 Number 5 1988 Nucleic Acids Research

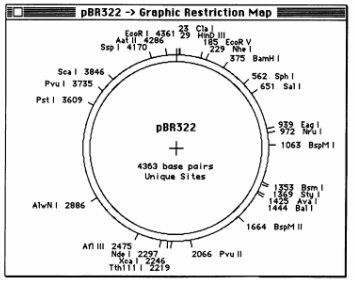
**'DNA Strider': a 'C' program for the fast analysis of DNA and protein sequences on the Apple Macintosh family of computers**

Christian Marck

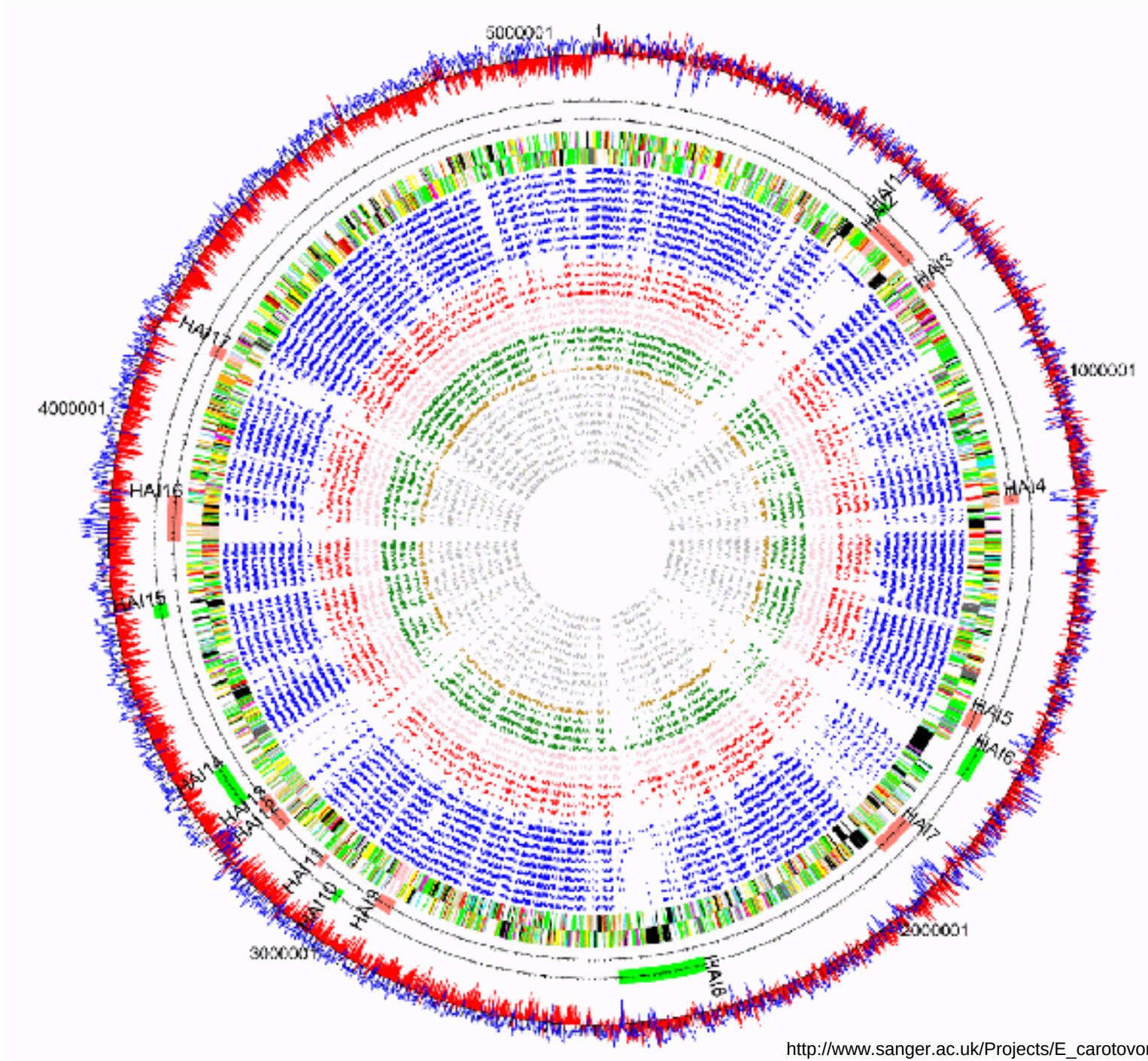
Service de Biochimie, Bâtiment 142, Département de Biologie, Centre d'Etudes Nucléaires de Saclay, 91191 Gif-sur-Yvette Cedex, France

Received August 17, 1987; Revised and Accepted November 15, 1987

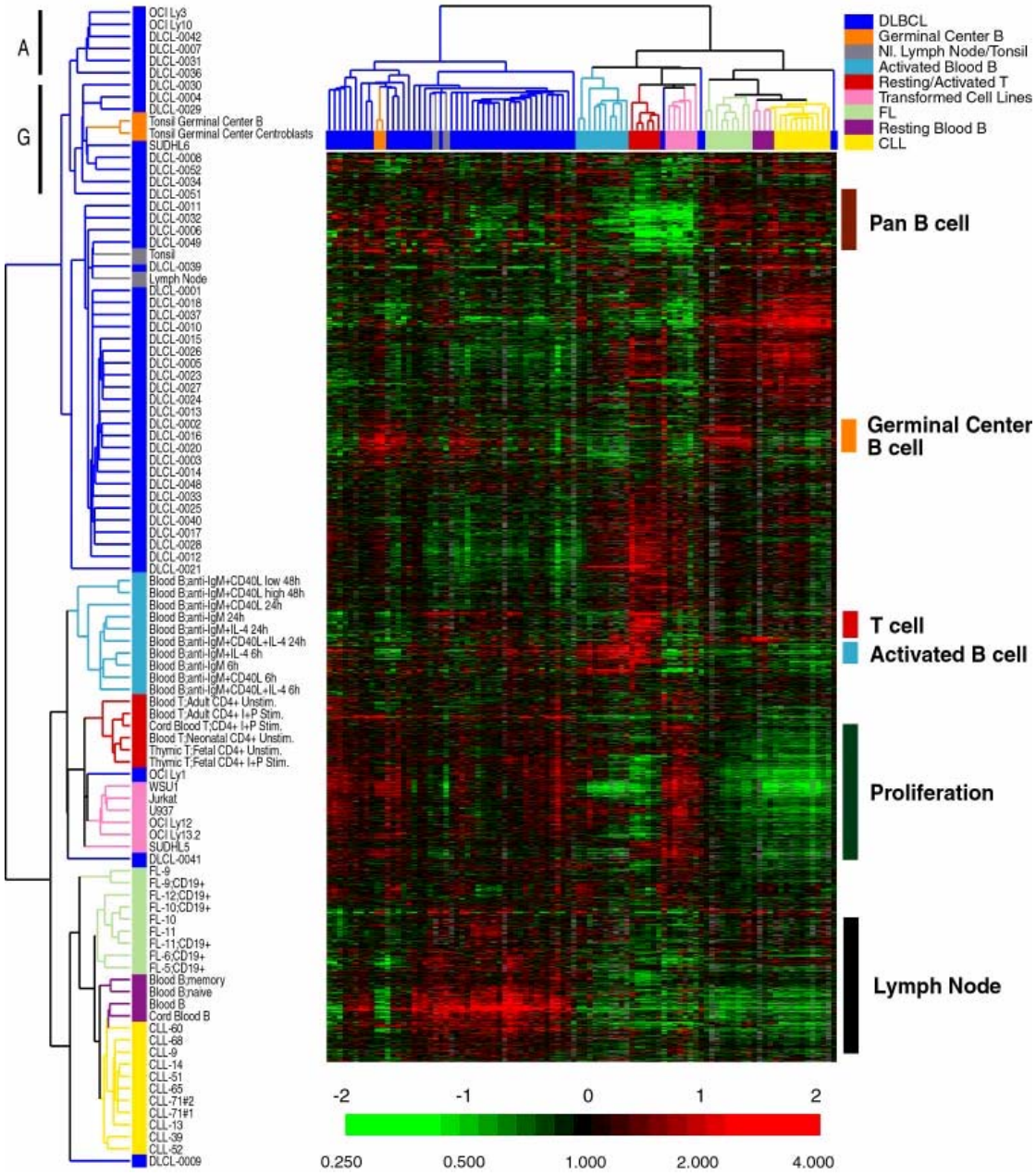


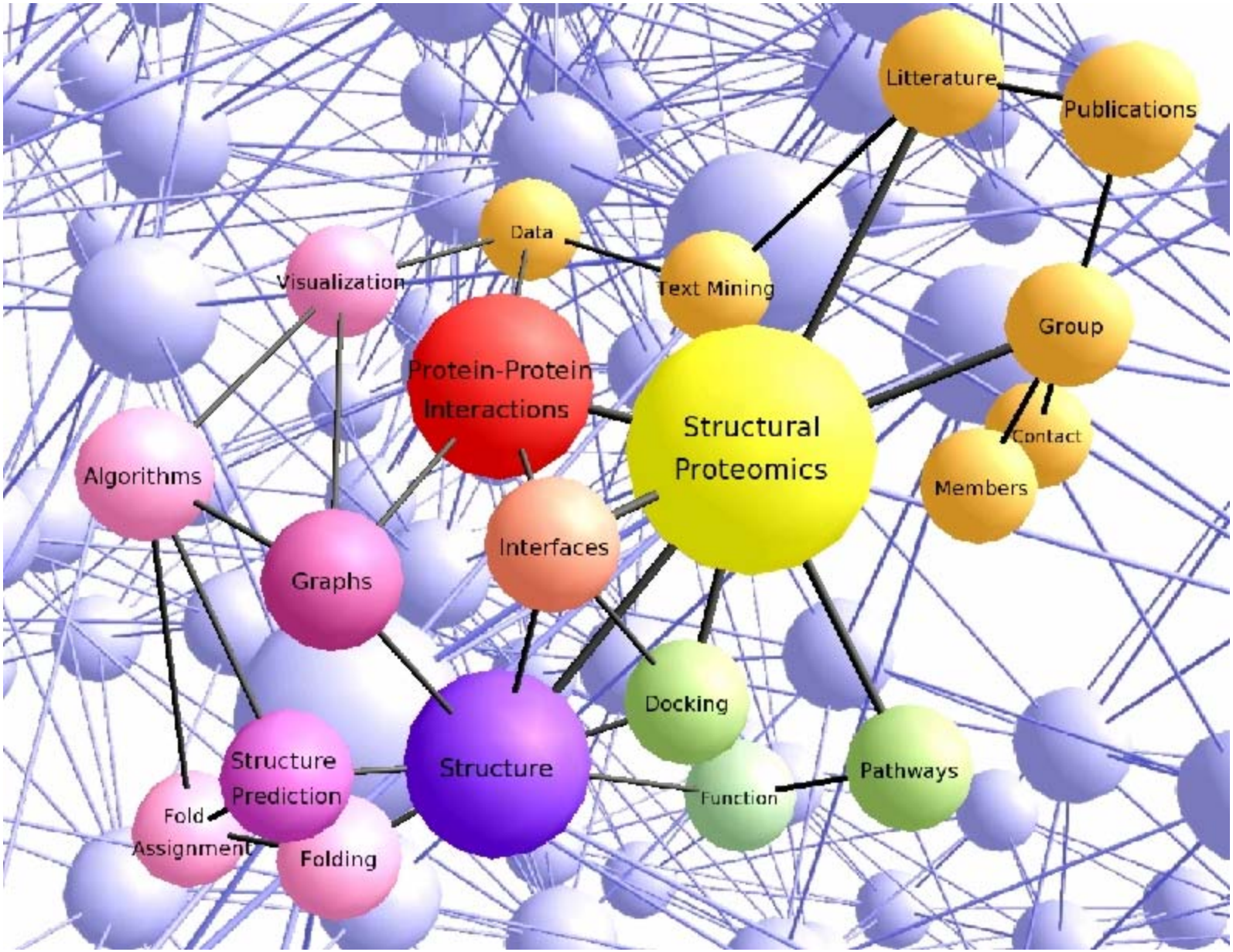

280.6 TFLOPS with 131072 nodes




http://www.sanger.ac.uk/Projects/E_carotovora/gfx/erwinia.gif



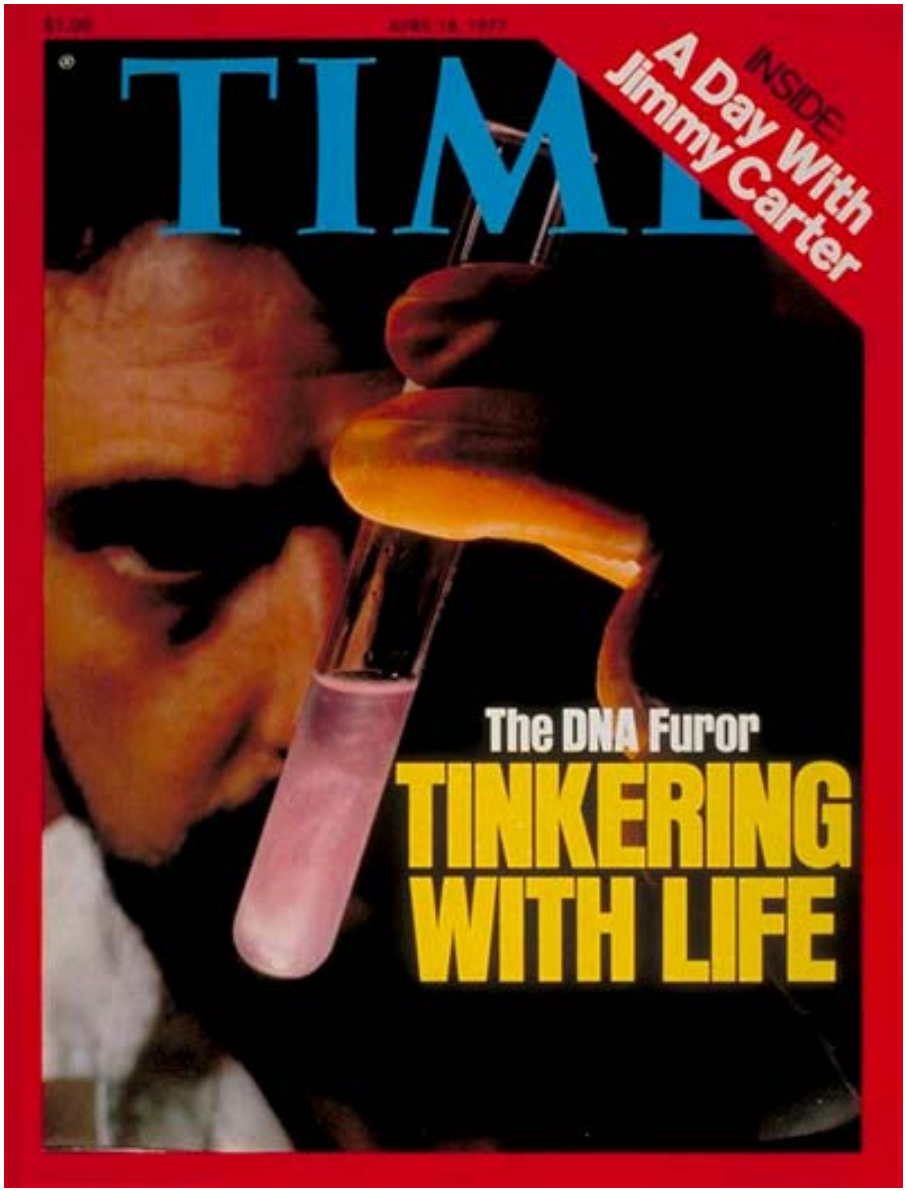

http://llmpp.nih.gov/lymphoma/images/large_figure1.jpg

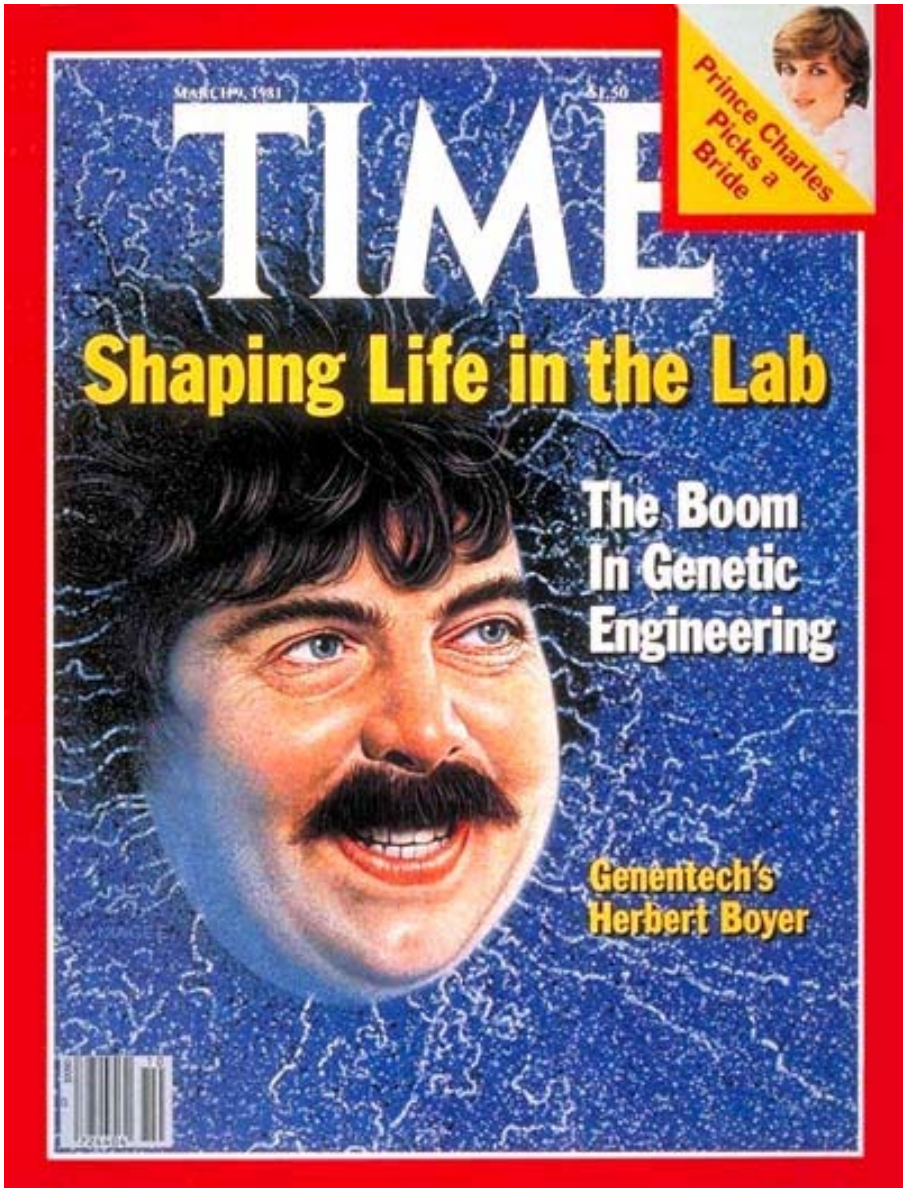



http://www.molgen.mpg.de/~lappe/photos/final_webPict.jpg

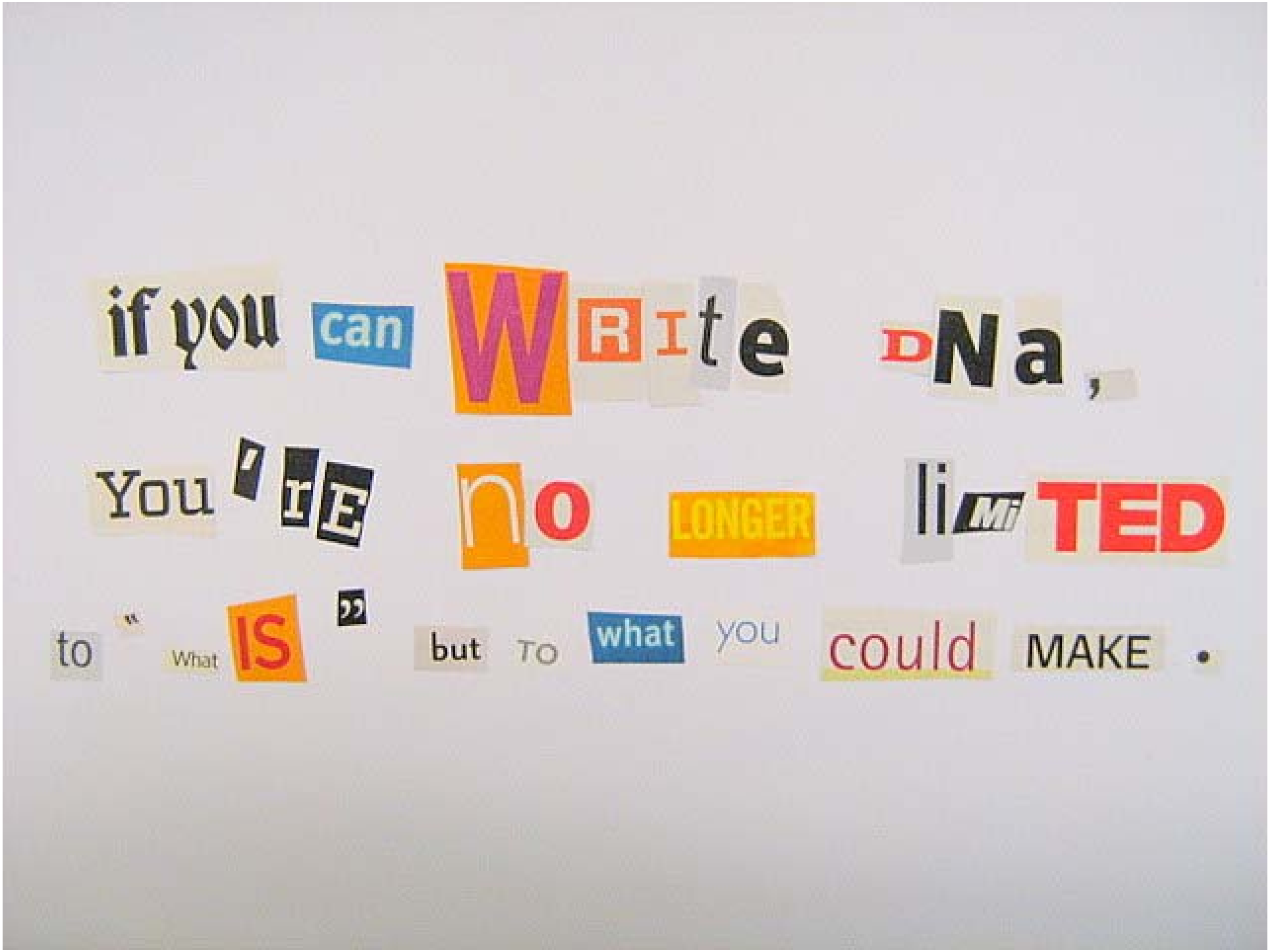
# Writing code: synthesis

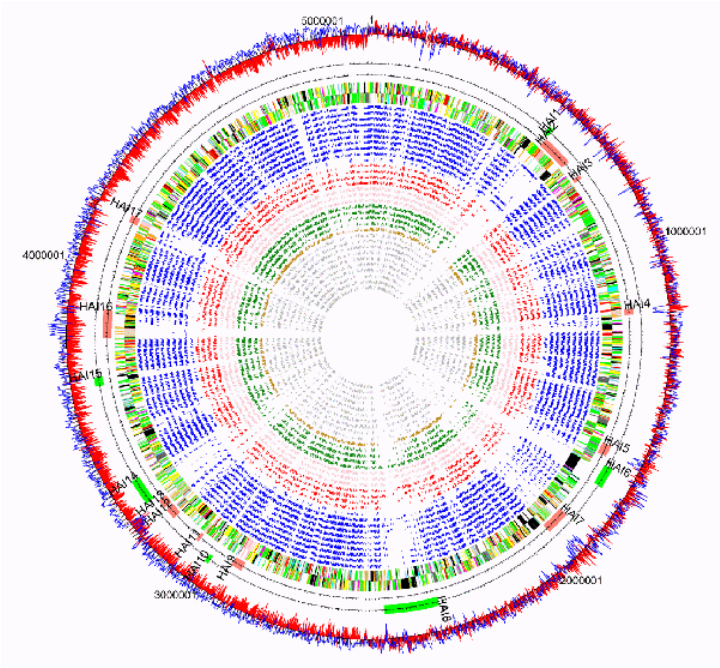
If we can’t build it, we don’t understand it.


TIME
INSIDE
A Day With Jimmy Carter
The DNA Furor
TINKERING WITH LIFE

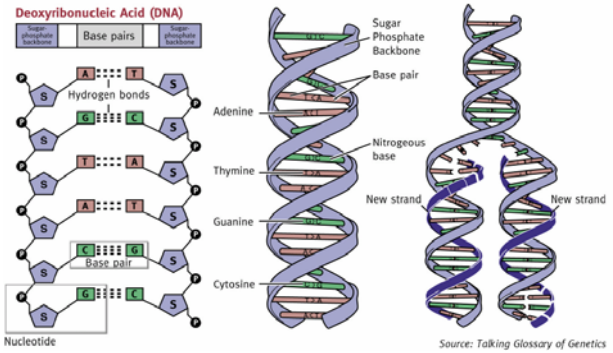

TIME
Prince Charles Picks a Bride
Shaping Life in the Lab
The Boom In Genetic Engineering
Genentech's Herbert Boyer

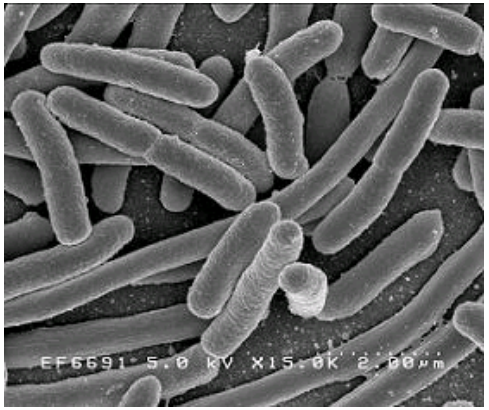

WARNING


if you can WRIte DNa,
You 're no LONGER limiTED
to " What IS " but TO what you could MAKE .



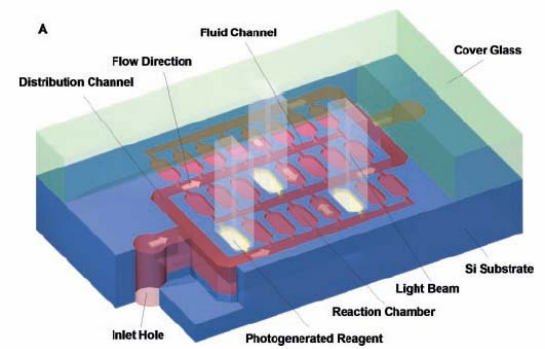
Digital DNA “design”

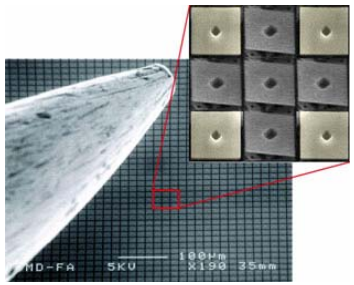


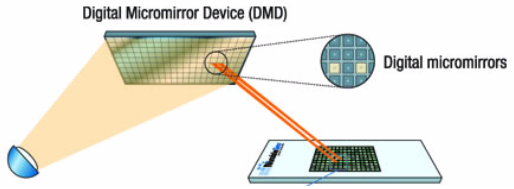



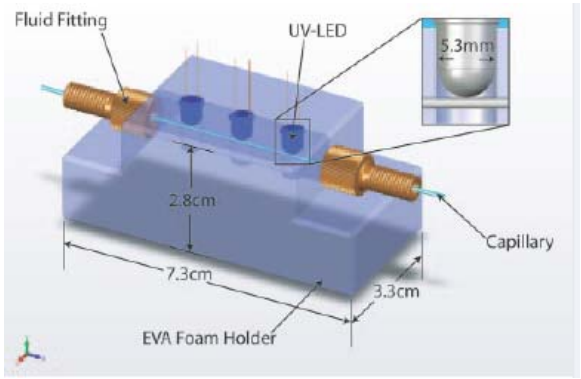

Physical DNA and outputs

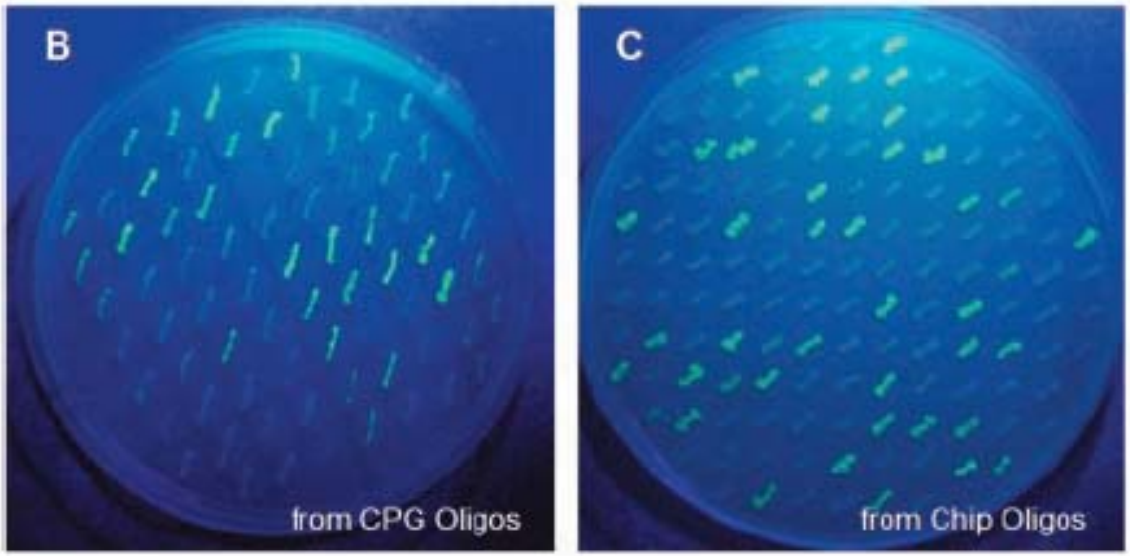

BECKMAN


A
Fluid Channel
Flow Direction
Distribution Channel
Cover Glass
Si Substrate
Light Beam
Reaction Chamber
Inlet Hole
Photogenerated Reagent

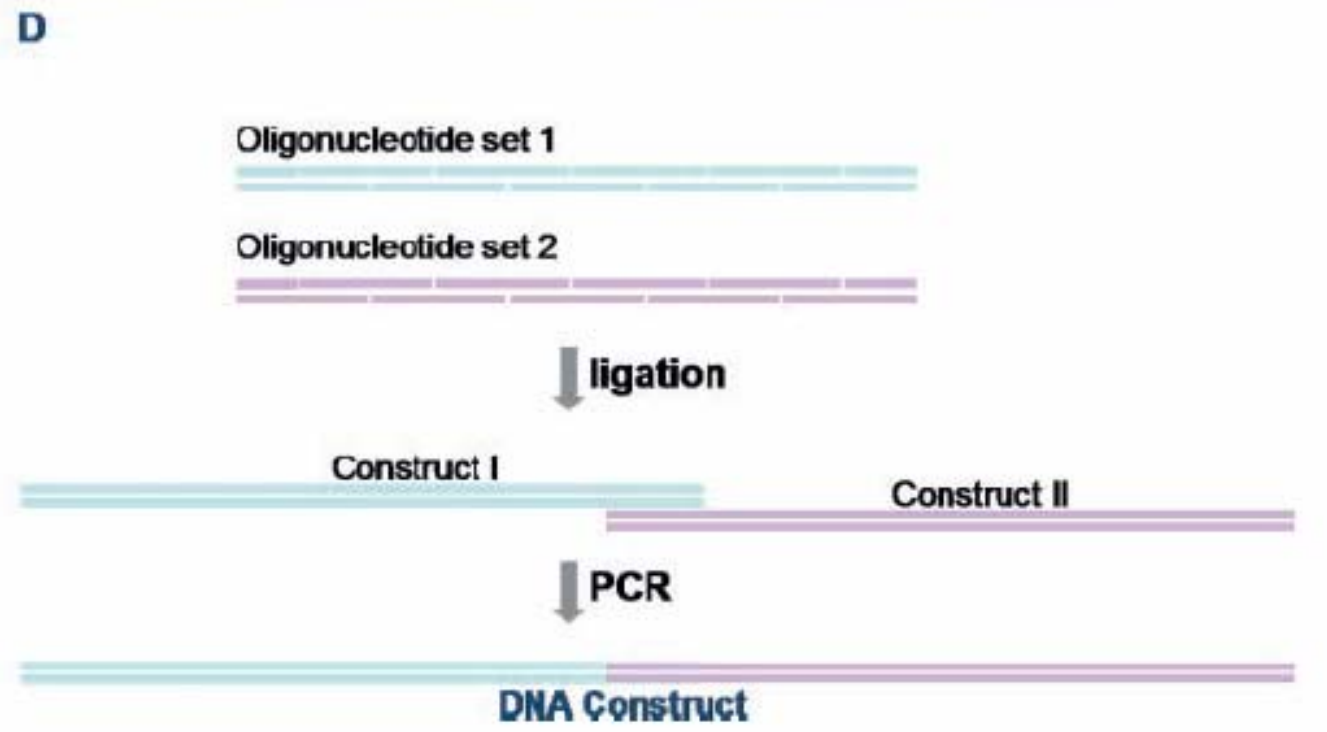



Digital Micromirror Device (DMD)
Digital micromirrors

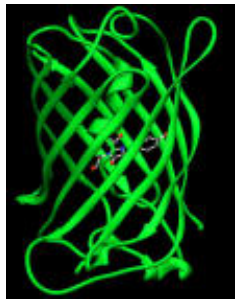

Fluid Fitting
UV-LED
5.3mm
2.8cm
Capillary
7.3cm
3.3cm
EVA Foam Holder



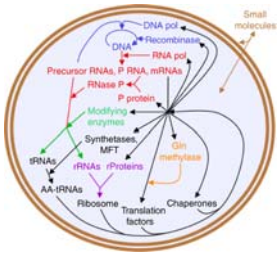

EGFP gene 714 bp



# Applications dependent on synthetic capabilities



single genes*

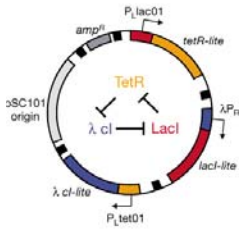


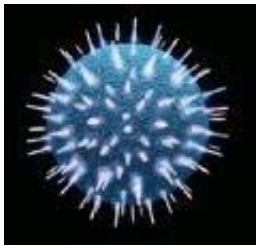

minimal life

**base pairs**

$10^2$ $10^3$ $10^4$ $10^5$ $10^6$ $10^7$

genetic circuits, viruses, GEMs



Engineered organisms

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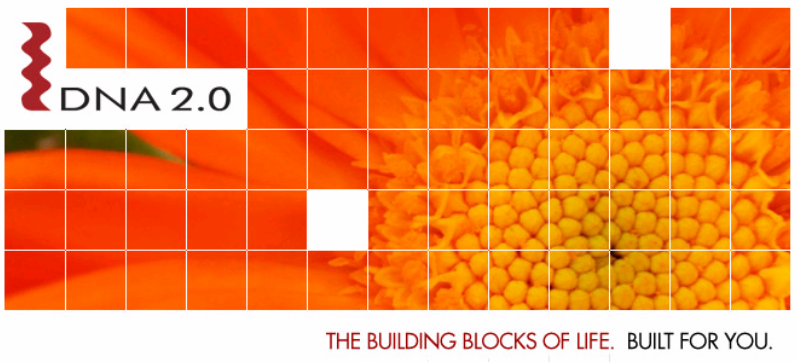



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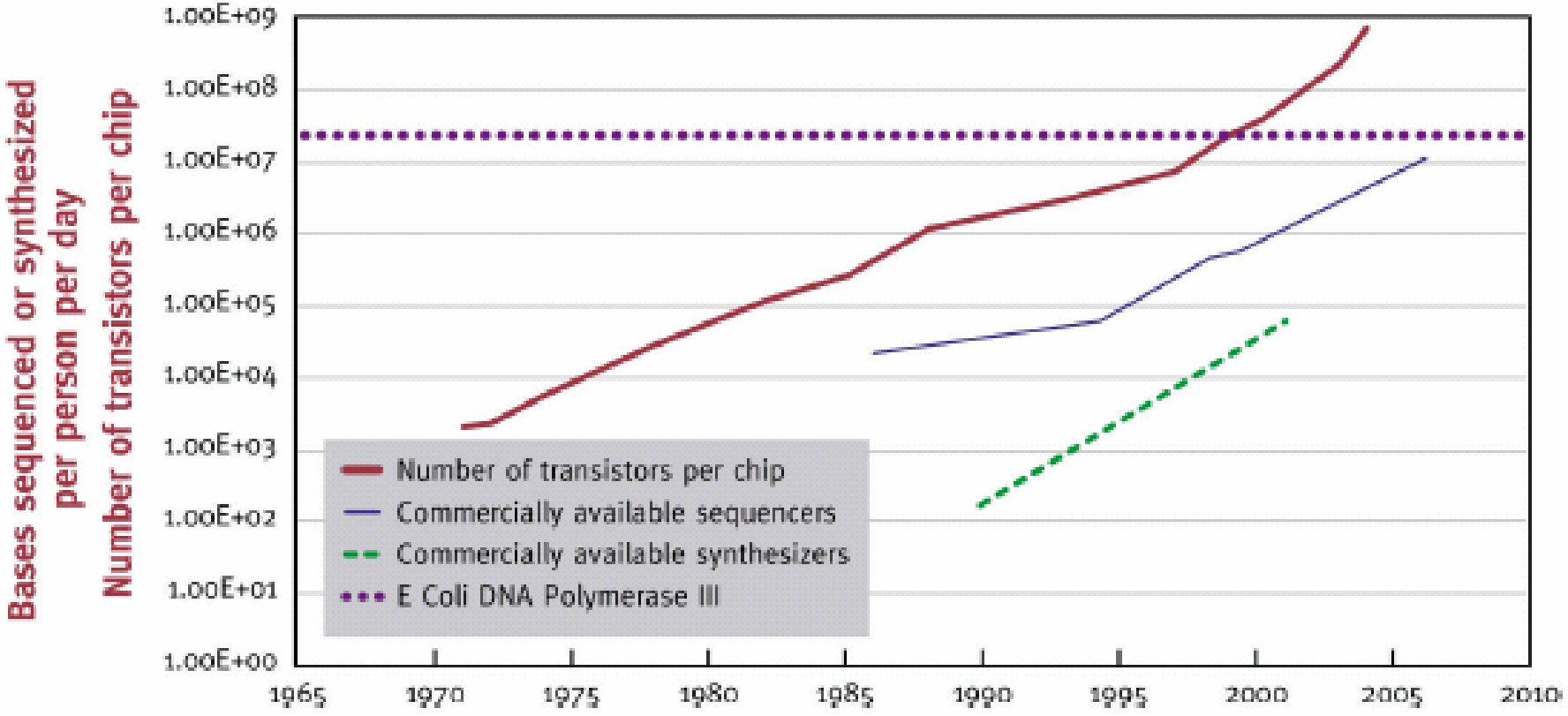
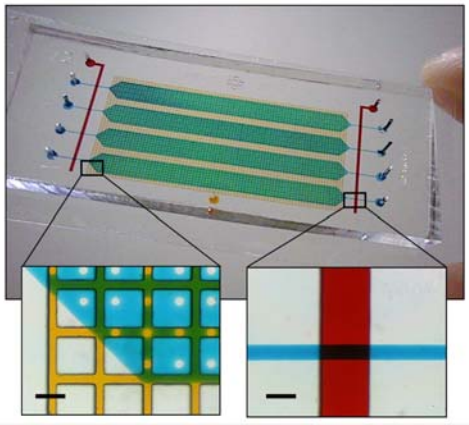
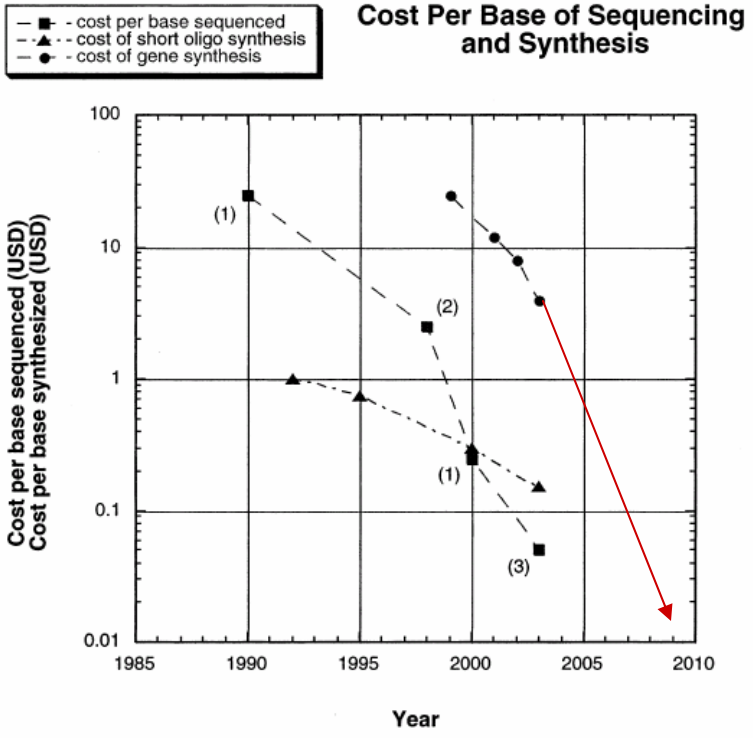


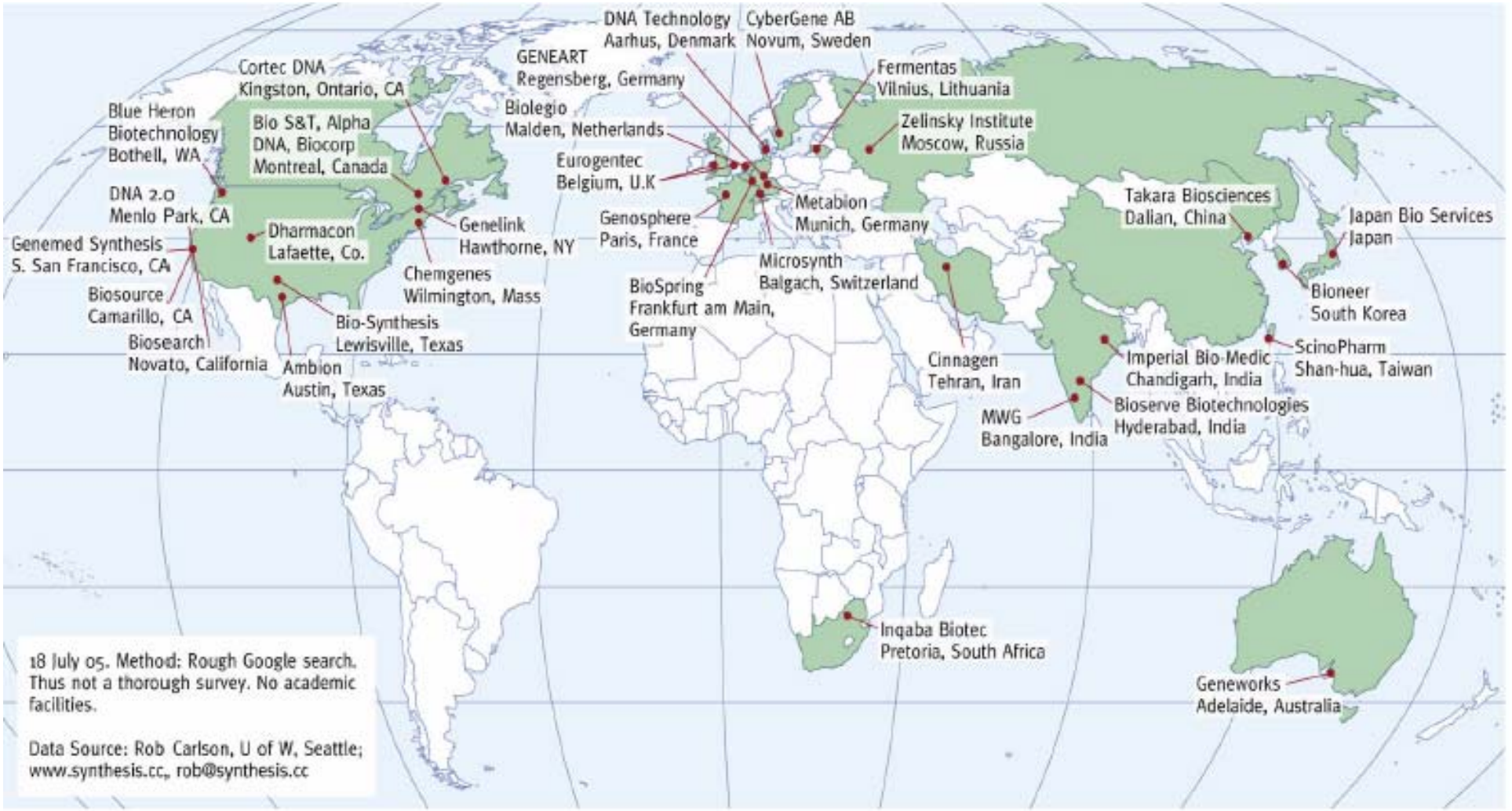

*Source: R. Carlson, Bio-era.*

- -5 years: 0.5 - 5kb, $10-$15/bp
- 0 years: 50 - 500kb $0.50-$1/bp
- +5 years: 5mb - 5gb <$0.0001/bp



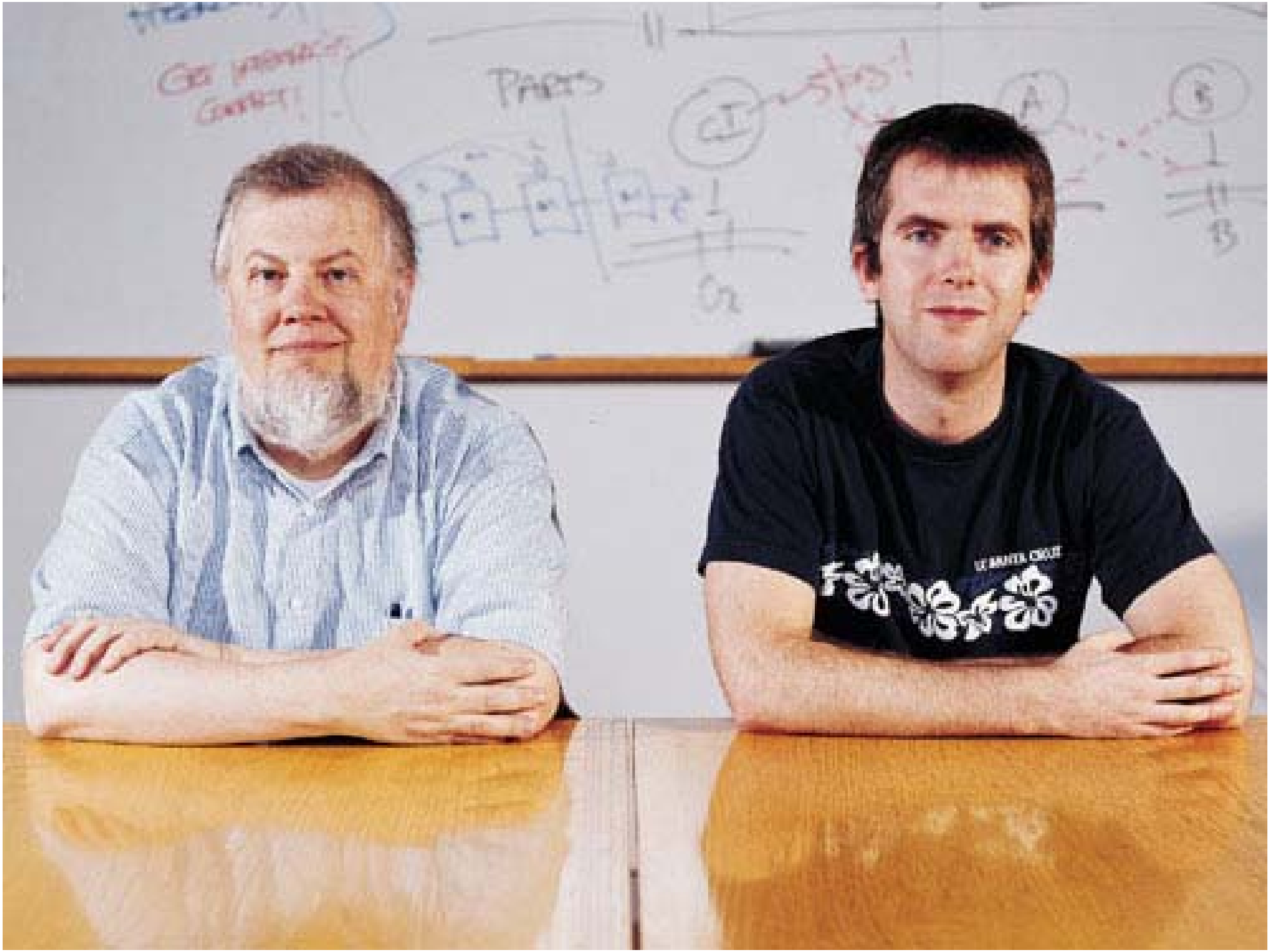



Carlson, R. (2003) The Pace and Proliferation of Biological Technologies

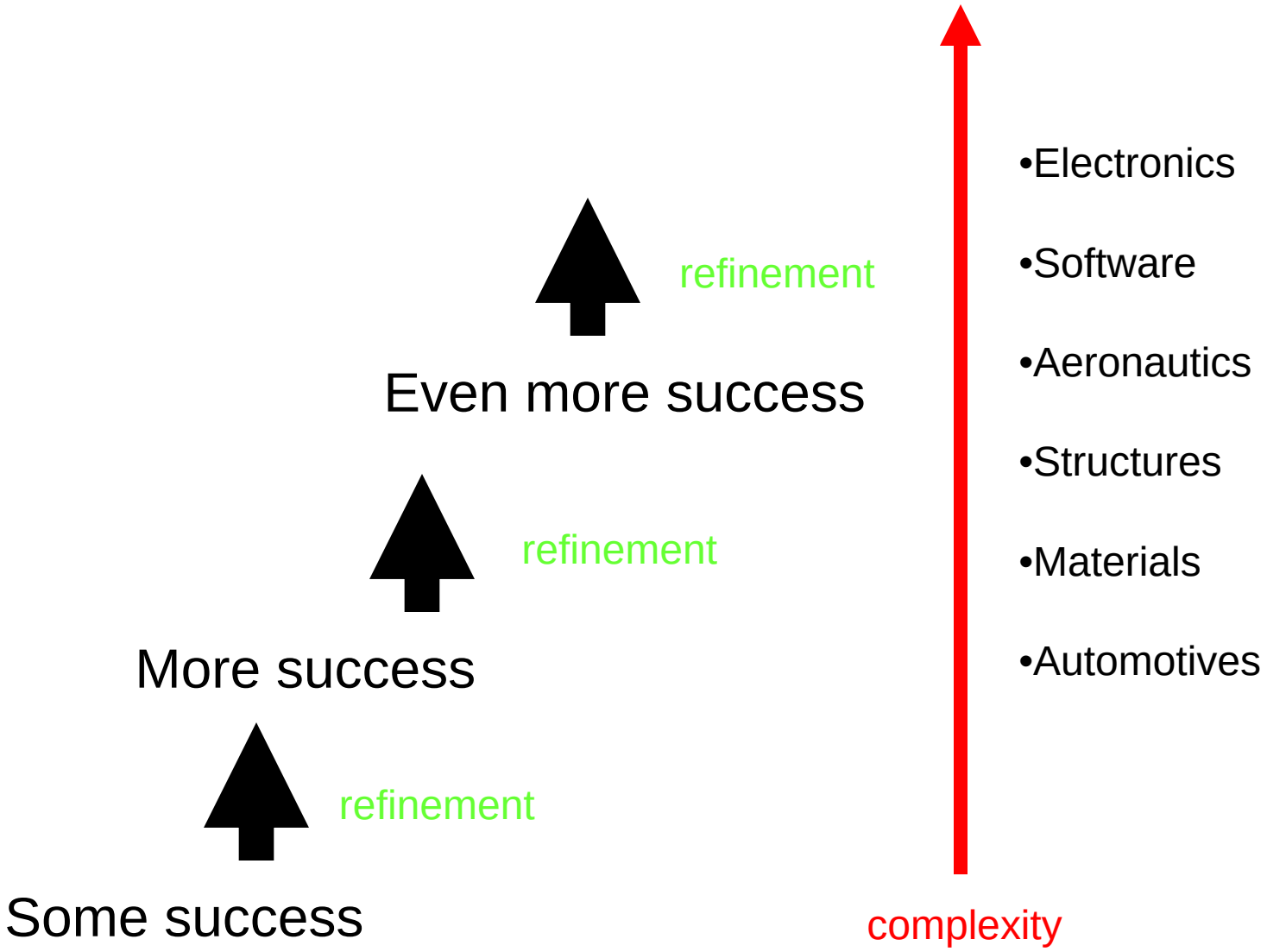



*Sources: Source: R. Carlson, G. Epstein, A. Yu (2005)*

# Engineering philosophy


PARTS

# Engineering process…



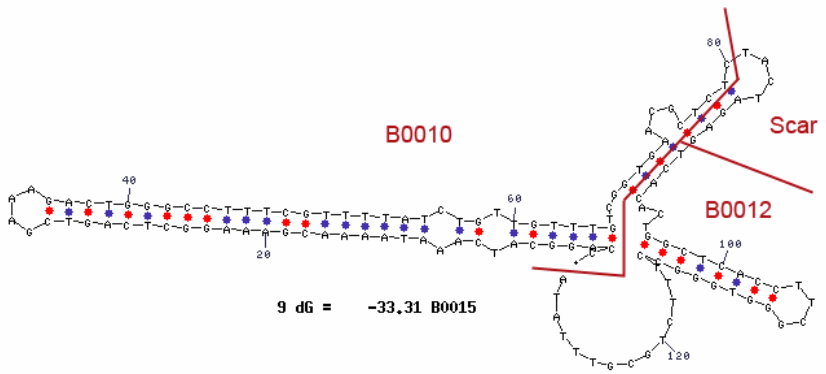
# F1760

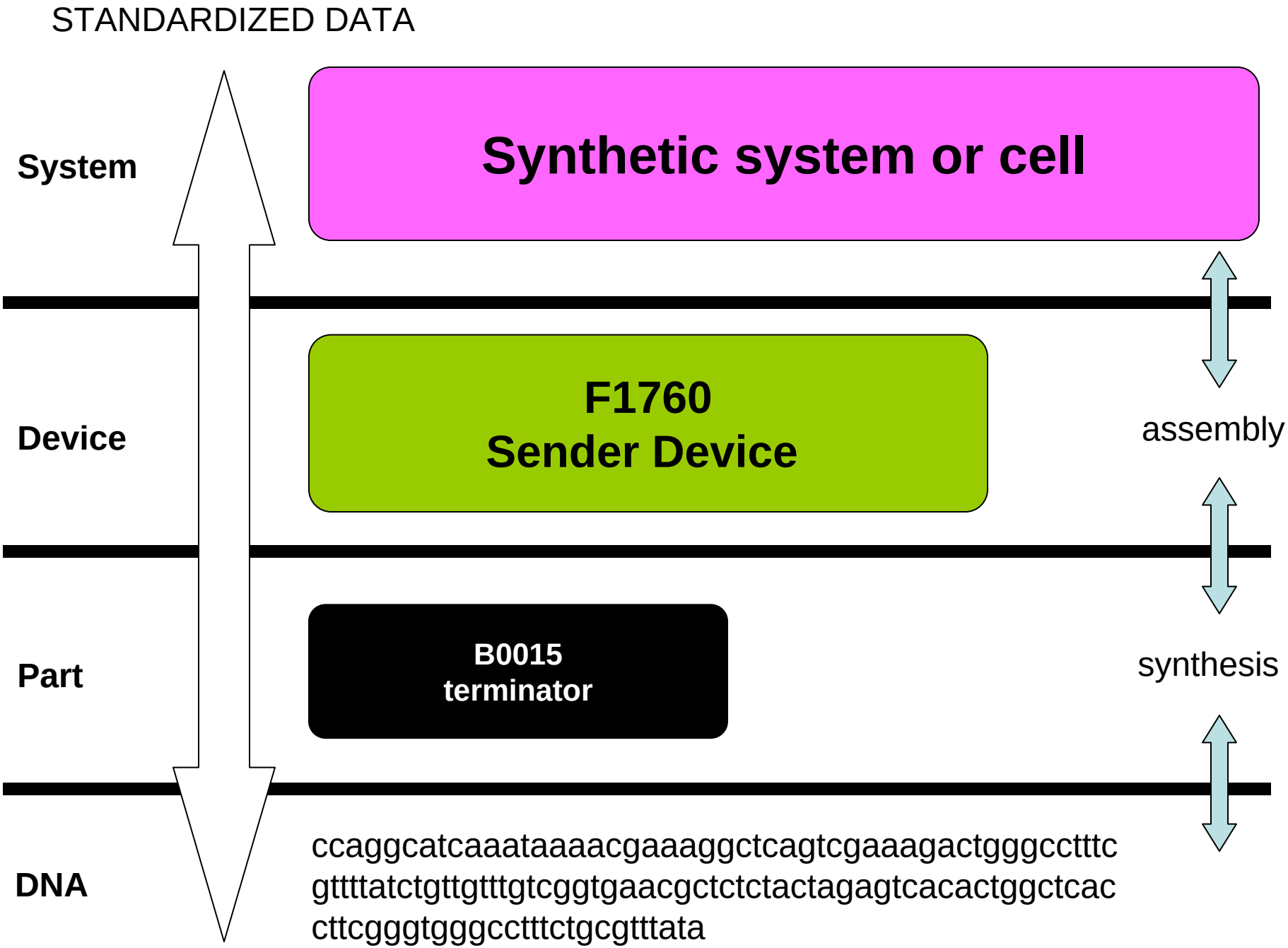
**Sender Device**

# B0015

**terminator**

Name: B0015
Type: Double terminator
Length 129 bp
Designed by: Reshma Shetty
Forward efficiency: 0.984
Reverse efficiency: .295




STANDARDIZED DATA
System
Synthetic system or cell
Device
F1760
Sender Device
assembly
Part
B0015
terminator
synthesis
DNA
ccaggcatcaaataaaacgaaaggctcagtcgaaagactgggcctttc
gttttatctgttgtttgtcggtgaacgctctctactagagtcacactggctcac
cttcgggtgggcctttctgcgtttata




# Transcriptional Regulators

jump to part

BBa_

navigation

- Main Page
- Browse Part Types
- iGEM Wiki
- Community portal
- Recent changes
- Recent part changes

resources

- User Accounts
- Add a Part
- Part Searches
- DNA Repositories
- Sequence Analysis
- Assembly Tool
- Help

search

Go Search

toolbox

- What links here

## Available repressible regulators (normally ON) -?-

Show 0 more parts

Edit

| -?- | Name | Description | Direction | Control -?- | Output Low | Output High | Length |
|---|---|---|---|---|---|---|---|
| A W | BBa_I14032 | promoter P(Lac) IQ | Forward | | | | 37 |
| A W | BBa_R0040 | promoter (tetR, negative) | Forward | aTc, tetracyline | | | 54 |
| A W | BBa_R0051 | promoter (lambda cI regulated) | Forward | lambda cI | | | 49 |

## Available inducible regulators (normally OFF) -?-

Show 0 more parts

Edit

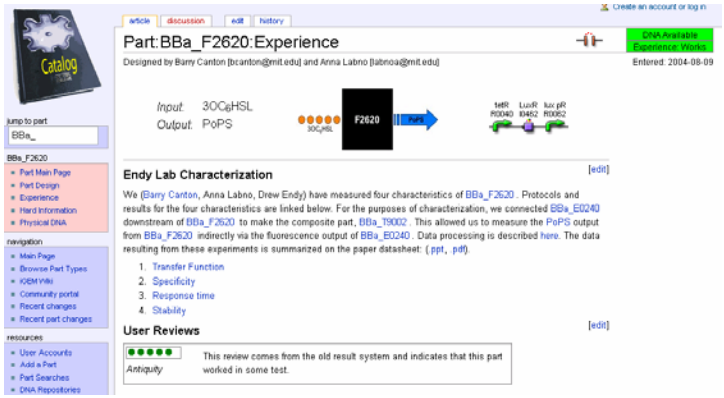
| -?- | Name | Description | Direction | Control -?- | Output Low | Output High | Length |
|---|---|---|---|---|---|---|---|
| A | BBa_I12007 | Modified lambda Prm promoter (OR-3 obliterated) | Forward | cI | | | 82 |
| A | BBa_R0062 | Promoter (luxR & HSL regulated -- lux pR) | Forward | luxR, HSL | | | 55 |
| A | BBa_R0079 | Promoter (LasR & PAI regulated) | Forward | PAI | | | 157 |
| A | BBa_R0080 | Promoter (AraC regulated) | Forward | araC | | | 149 |

## Available other regulators

Show 172 more parts

Edit

| -?- | Name | Description | Direction | Control -?- | Output Low | Output High | Length |
|---|---|---|---|---|---|---|---|
| A W | BBa_I0500 | Inducible pBad/araC | Forward | araC, arabinose | | | 1210 |
| A W | BBa_I13453 | Pbad promoter | | | | | 130 |
| A W | BBa_J13002 | TetR repressed POPS/RIPS generator | Forward | ATc | | | 74 |
| A W | BBa_J13023 | 3OC6HSL+LuxR dependent POPS/RIPS generator | | | | | 117 |
| A W | BBa_J23100 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23101 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23102 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23103 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23104 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23105 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23106 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23107 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23108 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23109 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23110 | constitutive promoter family member | | | | | 35 |
| A W | BBa_J23111 | constitutive promoter family member | | | | | 35 |


# BBa_F2620

3OC$_6$HSL → PoPS Receiver

http://parts.mit.edu/registry/index.php/Part:BBa_F2620

Authors:
Barry Canton [bcanton@mit.edu]
Anna Labno [labnoa@mit.edu]

Last Update: 15 January 2007

## Description

A transcription factor (LuxR, BBa_C0062) that is active in the presence of cell-cell signaling molecule 3OC$_6$HSL is controlled by a TetR-regulated operator (BBa_R0040). Device input is 3OC$_6$HSL. Device output is PoPS from a LuxR-regulated operator. If used in a cell containing TetR then a second input signal such as aTc can be used to produce a Boolean AND function.

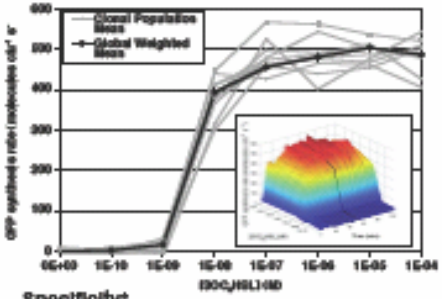
## Characteristics

*Input Swing:* 1E-9 to 1E-6 M 3OC$_6$HSL, exogenous
*Output Swing:* 0±1 to 503±1 GFP molecules cfu$^{-1}$ s$^{-1}$
*Switch Point:* 7±1 nM 3OC$_6$HSL, exogenous
*LH Response:* 9 min ($t_{50\%}$), 27 min ($t_{90\%}$)

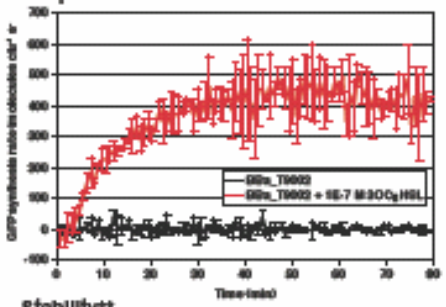
## Key Parts

*BBa_R0040:* TetR-regulated operator
*BBa_C0062:* luxR ORF
*BBa_R0062:* LuxR-regulated operator

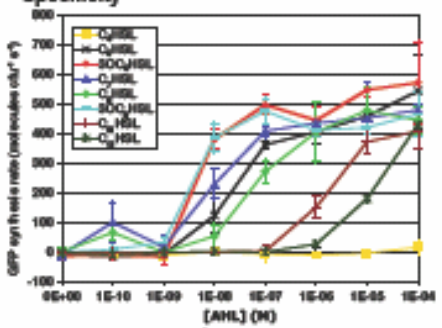
### Transfer Function*



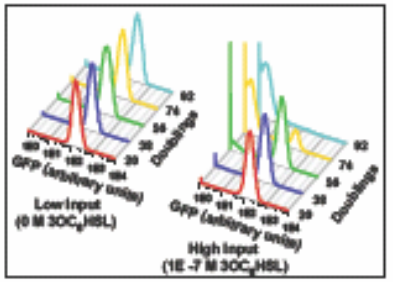

### Response Time*




### Specificity*




### Stability**




## Demand (low/high input)

*Translational:* 256/8048 ribosomes cfu$^{-1}$
3.8E3/1.2E5 charged tRNA cfu$^{-1}$ s$^{-1}$

## Stability (low/high input)

*Genetic:* >92/74 replication events**
*Performance:* >92/74 replication events**

## Compatibility

*Chassis:* Compatible with *MC4100*, *MG1655*, and *DH5α*
*Plasmids:* Compatible with *pSB3K3* and *pSB1A2*
*Devices:* Compatible with *E0240*, *E0430* and *E0434*
Crosstalk with systems containing *TetR (C0040)*
*Signaling:* Crosstalk with input molecules similar to 3OC$_6$HSL

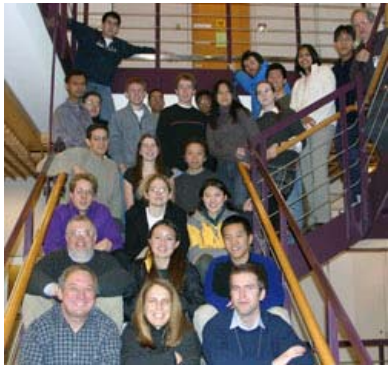
## Conditions (abridged)

*Output:* Indirect via *BBa_E0240*
*Vector:* pSB3K3
*Chassis:* MG1655
*Culture:* Supplemented M9, 37°C
**Equipment:* PE Victor3 plate reader
***Equipment:* BD FACScan cytometer

Signaling Devices

Shares:

- DNA parts
- DNA code
- Protocols
- Experience
- Publications



2006 Jamboree – 400 gengineers

# Designs on life

Earlier this month, students from around the world locked horns in competition. Their challenge was to build functioning devices out of biological parts. **Erika Check** finds out how they got on.

Even if you're thinking big, you usually have to start small. Especially, as a group of Swiss students found, when big means counting to infinity. The team was drawing up a blueprint for the world's first counting machine made entirely of biological parts. Although they had their sights on loftier numbers, they opted to go no higher than two. If the plan worked, it would be a proof-of-principle for a much larger tallying device.

The group, from the Federal Institute of Technology (ETH) in Zurich, was one of 17 teams unveiling their projects at the first international Intercollegiate Genetically Engineered Machine (iGEM) competition, held at the Massachusetts Institute of Technology (MIT) in Cambridge on 5 and 6 November. The event attracted students from all over the world to design and build machines made entirely from biological components such as genes and proteins. They drew up grand designs for bacterial Etch-a-Sketches, photosensitive t-shirts, thermometers and sensors. And if none of the designs succeeded completely, that was more because of the limitations of the nascent science of synthetic biology than any lack of enthusiasm, creativity or hard work.

Synthetic biology aims to merge engineering approaches with biology. Researchers working at the most basic level are copying simple biological processes, such as the production of a protein from a gene. They break the process down into its component elements, such as a gene and the pieces of DNA and other molecules that control its activity. They then string these elements together to build a module they know will behave in a particular way — say, oscillate between producing and not producing a protein, or produce a protein that can switch another module on or off.

It is these kinds of components — oscillators and switches — that engineers order from suppliers and link together to build more complex electronic circuits and machines. Synthetic biologists are trying to develop a similar armoury of biological components, dubbed BioBricks, that can be inserted into any genetic circuit to carry out a particular function. Scientists at MIT have established a Registry of Standard Biological Parts, a catalogue of BioBricks that theoretically

Bidding for glory: teams from the ETH in Zurich (top), Cambridge, UK, (bottom right) and Massachusetts at the first International Intercollegiate Genetically Engineered Machine competition.

from the ground up. To do so, they have commandeered a time-honoured engineering tradition: the student competition. The iGEM event began life as a project class for MIT students in 2003. Last year, it was thrown open to other US universities, and this year it went international. The organizers hope to attract 30 to 50 [illegible]

selection of designs. Students from the University of Cambridge, UK, tried to make a circuit that could control the movement of *Escherichia coli* bacteria. They aimed to engineer the bacteria to contain a switch governing their sensitivity to the sugar maltose. With the switch off, the microbes would ignore the sugar. Tripping



BRIEF COMMUNICATIONS

## Engineering *Escherichia coli* to see light

These smart bacteria 'photograph' a light pattern as a high-definition chemical image.

We have designed a bacterial system that is switched between different states by red light. The system consists of a synthetic sensor kinase that allows a lawn of bacteria to function as a biological film, such that the projection of a pattern of light on to the bacteria produces a high-definition (about 100 mega-pixels per square inch), two-dimensional chemical image. This spatial control of bacterial gene expression could be used to 'print' complex biological materials, for example, and to investigate signalling pathways through precise spatial and temporal control of their phosphorylation steps.

Plants and some bacteria use a class of protein photoreceptors known as phytochromes to control phototaxis, photosynthesis and the production of protective pigments[1–3]. Photoreceptors are not found in enterobacteria, such as *Escherichia coli*, so we created a light sensor that functions in *E. coli* by engineering a chimaera that uses a phytochrome from a cyanobacterium.

A phytochrome is a two-component system that consists of a membrane-bound, extracellular sensor that responds to light and an intracellular 'response-regulator'. The response-regulators of most phytochromes do not have DNA-binding domains and do not directly regulate gene expression, so we fused a cyanobacterial photoreceptor to an *E. coli* intracellular histidine kinase domain (Fig. 1a, and see supplementary information). This design was based on the well studied *E. coli* EnvZ–OmpR two-component system, which normally regulates porin expression in response to osmotic shock[4]. The EnvZ histidine kinase domain has been used for the construction of functional chimaeras[5,6], and a plant phytochrome has

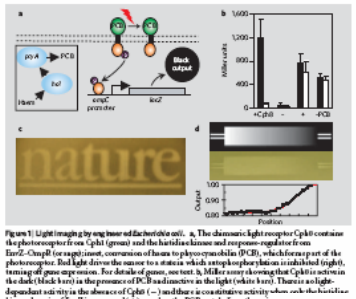


Figure 1 | Light imaging by engineered *Escherichia coli*. a, The chimaeric light receptor Cph8 contains the photoreceptor from Cph1 (green) and the histidine kinase and response-regulator from EnvZ–OmpR (or vice versa; insert, conversion of beam to phycocyanobilin (PCB), which forms part of the photoreceptor. Red light drives the sensor to a state in which autophosphorylation is inhibited (right), turning off gene expression. For details of genes, see text. b, Miller assay showing that Cph8 is active in the dark (black bars) as the precursor of PCB and inactive in the light (white bars). There is a light-dependent activity in the absence of Cph8 (−) and there is constitutive activity when only the histidine kinase domain of EnvZ is expressed (+), or when the PCB metabolic pathway is [illegible]. c, When an image is projected on to a bacterial lawn, the LacZ reporter is expressed in the illuminated regions. d, Transfer function of the circuit. As the intensity of the light is increased in a linear gradient projected from a 35-mm slide, the circuit output gives a graded response.

enzymatically produces a black compound.

The part of the photoreceptor that responds to light, phycocyanobilin, is not naturally produced in *E. coli*. We therefore introduced two phycocyanobilin-biosynthesis genes (*ho1* and *pcyA*) from *Synechocystis* that convert haem into phycocyanobilin[8] (parts [illegible]_I15008, BBa_I15009; MIT Registry of Standard Biological Parts) (Fig. 1a, Inset). Individual Cph1–EnvZ chimaeras were then incubated at 37 °C for 4 h with broad-spectrum light and assayed for expression of the LacZ reporter. The chimaera Cph8 (BBa_I15010) produced a particularly strong response to light (Fig. 1b).

For bacterial photography, we grew a lawn of bacteria on agar. The lacZ reporter was visualized by addition of 5-gal (3,4-cyclohexenoesculetin-β-D-galactopyranoside); LacZ catalyses the formation of a stable, insoluble, dark precipitate from 5-gal. Light repressed the expression in the bacteria, giving a high-contrast replica of the applied image on the biological film, [illegible] appeared light and dark (Fig. 1c, and see supplementary information). The lacZ activity showed a increasing light intensity, the brightest light (Fig.

Our creation of a novel an image-processing f the power and accessibil methods available in th thetic biology. The pri light regulation should to be spatially and tar individual cells and in potential application in raphy, manufacture o composites and the s signalling networks.

Anselm Levskaya*, Aaron J. Tabor†, Zachary Booth Lauer†, Matthew Levy†, Alexander Scouras†, Andrew D. Ellington†, Edward M. Marcotte†‡, C






# Genetic 'Jamboree' draws innovators

The Boston Globe

## Science students the world over share research

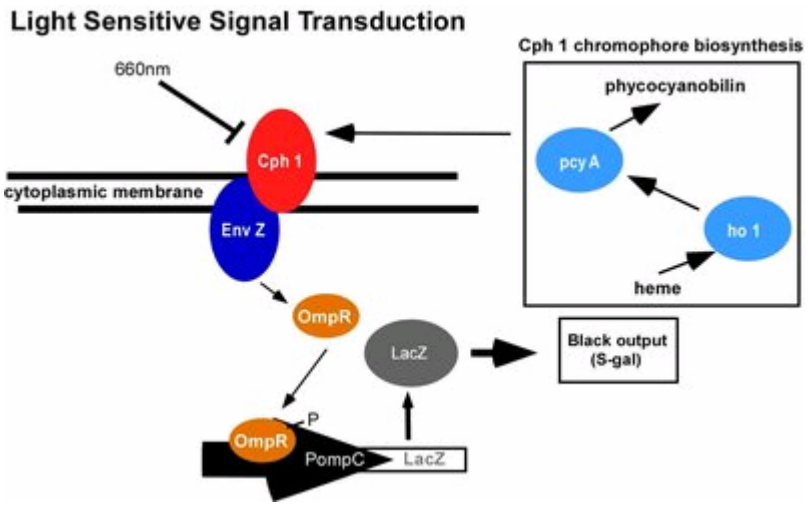
At MIT's International Genetically Engineered Machine Competition yesterday, the audience listened to a presentation on synthetic biology. (John Tlumacki/ Globe Staff)

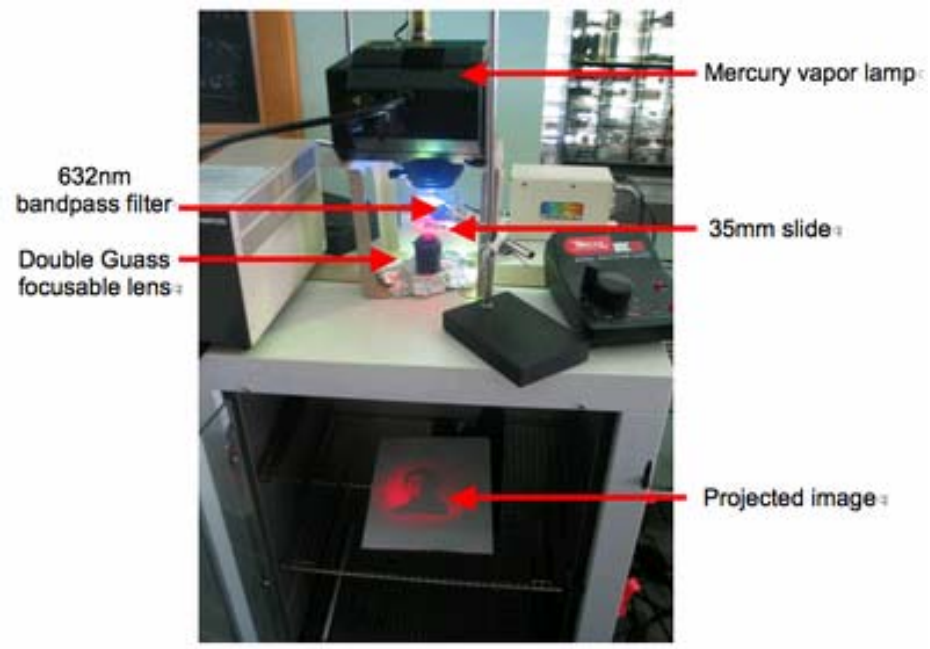
COVER STORY

By Carl Zimmer

**Scientist of the Year**

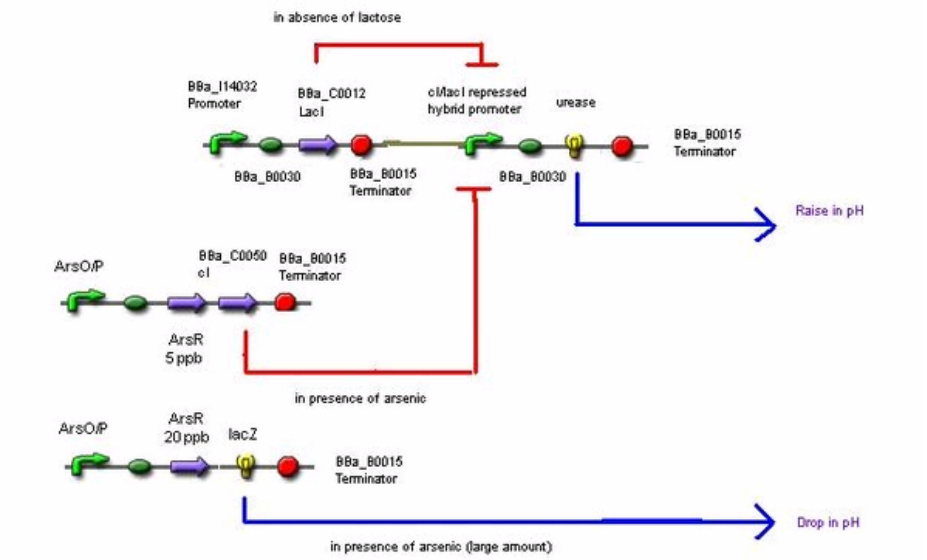
Jay Keasling is developing ways to program DNA as easily as people program computers.

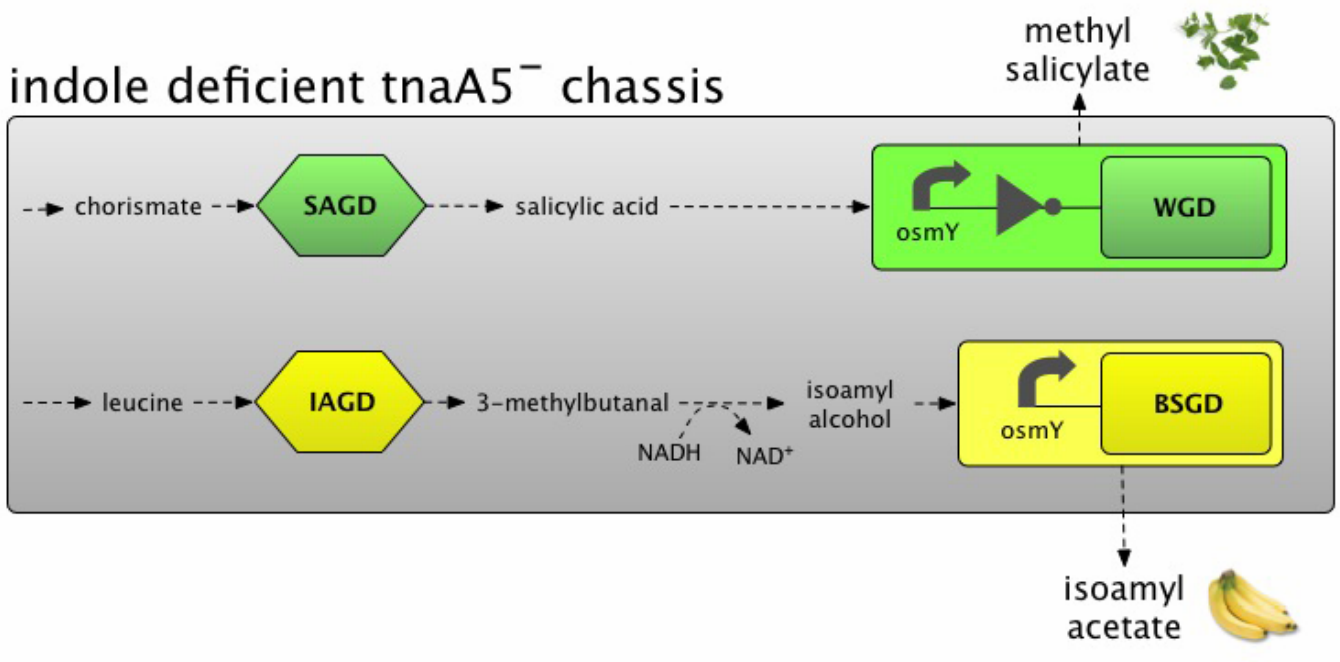

Light Sensitive Signal Transduction
Cph 1 chromophore biosynthesis
660nm
phycocyanobilin
Cph 1
pcy A
cytoplasmic membrane
Env Z
ho 1
heme
OmpR
LacZ
Black output
(S-gal)
P
OmpR
PompC
LacZ


Mercury vapor lamp
632nm
bandpass filter
35mm slide
Double Guass
focusable lens
Projected image


Hello
World


HOOK 'EM HORNS


in absence of lactose
BBa_I14032
Promoter
BBa_C0012
LacI
cI/lacI repressed
hybrid promoter
urease
BBa_B0015
Terminator
BBa_B0030
BBa_B0015
Terminator
BBa_B0030
Raise in pH
ArsO/P
BBa_C0050
cI
BBa_B0015
Terminator
ArsR
5 ppb
in presence of arsenic
ArsO/P
ArsR
20 ppb
lacZ
BBa_B0015
Terminator
Drop in pH
in presence of arsenic (large amount)


indole deficient tnaA5⁻ chassis
methyl salicylate
chorismate
SAGD
salicylic acid
osmY
WGD
leucine
IAGD
3-methylbutanal
NADH
NAD+
isoamyl alcohol
osmY
BSGD
isoamyl acetate

# iGEM 2007

- 57 teams – 20 countries

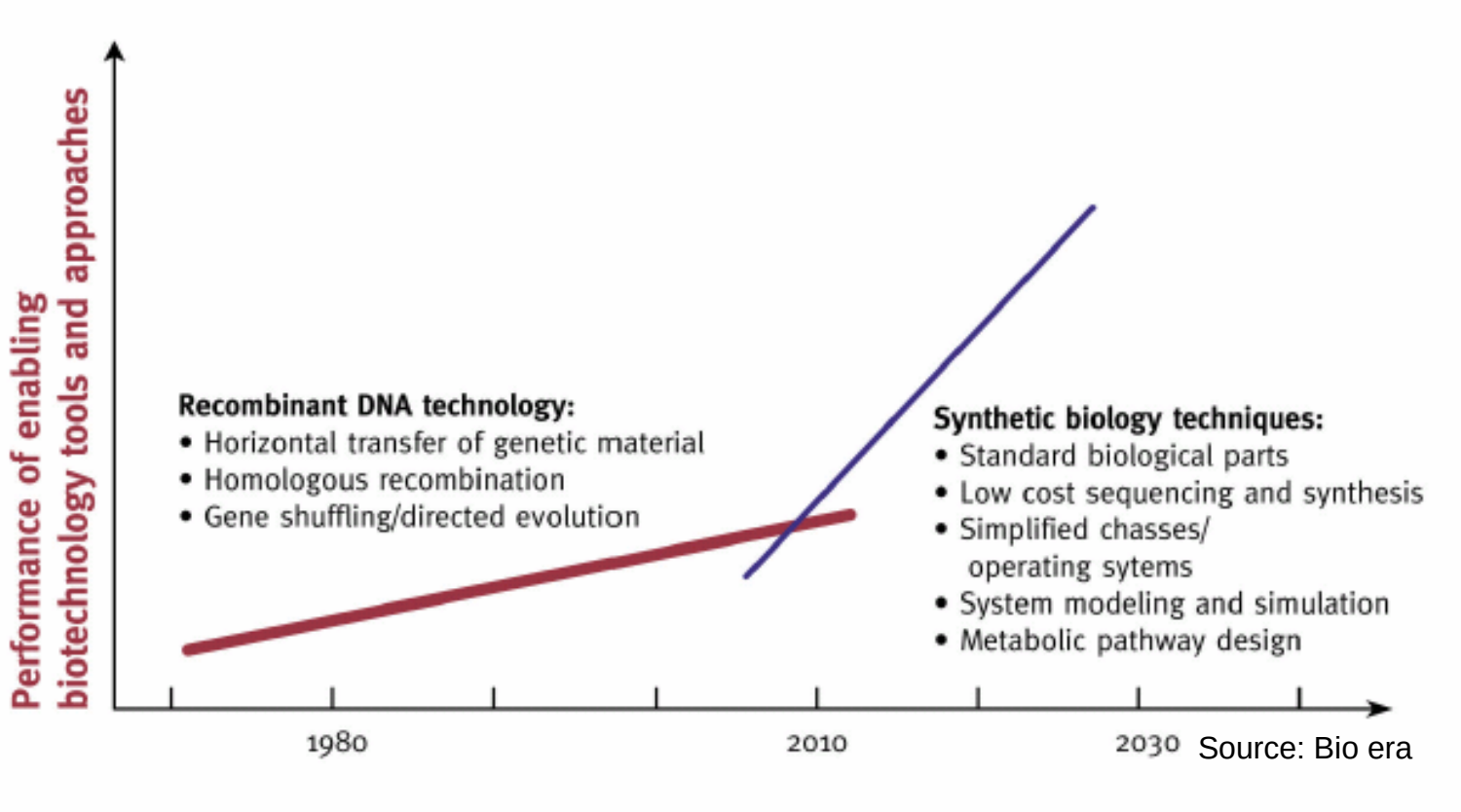
- USA (26)
- Scotland (3)
- Colombia
- Italy (2)
- Mexico
- Taiwan
- Russia
- Germany
- South Africa
- Middle East
- Canada (6)
- Japan (2)
- Australia
- England
- Switzerland
- China (4)
- Spain
- India
- France
- **Slovenia**

# U of A iGEM Team

- Biobutanol project – "*Plan B*"
- Moving metabolic pathway from Clostridium into E. coli

# Opportunities for Alberta

# Synthetic biology is going to grow fast!




Source: Bio era

# PIMP MY GENOME!

## SYNTHETIC BIOLOGY:
## A PLAN FOR ENGINEERING BIOLOGY

**Wednesday April 4, 2007**
University of Alberta, Telus Centre, Room 150
111 Street and 87 Avenue
Edmonton, AB

**Doors open and refreshments - 3:00 PM**
**Presentation - 3:30 PM**

*Complimentary return bus transportation will be provided to guests from the University of Calgary.*

**Join Drew Endy, a leader in synthetic biology from MIT, for an engaging look at how biological engineering is changing. Find out how the latest advances in this new era of biology are helping make R&D faster, cheaper and easier.**

Drew is a fellow in the Department of Biology and the Biological Engineering Division at MIT. He co-founded the MIT Synthetic Biology working group and the Registry of Standard Biological Parts. He is also co-founder of iGEM, the International Genetically Engineered Machine competition, Codon Devices Inc., a venture-funded startup that is working to develop next-generation DNA synthesis technology, and the BioBricks Foundation, a not-for-profit organization that is working to develop legal and economic strategies needed to support open biotechnology. Drew's work has been featured in *The Economist*, *Forbes*, *WIRED*, *Scientific American* and the *New York Times*.

**For registration and more information, please visit www.albertaingenuity.ca.**

ALBERTA INGENUITY FUND

UNIVERSITY OF ALBERTA

*The Alberta Ingenuity Fund supports science and engineering research of the highest calibre, to create a prosperous future for the province. It draws funding from a $1 billion endowment established and managed by the Government of Alberta to build the capacity for innovation, especially in areas with long lasting social and economic impact.*

*Engineering synthetic biological constructs will become the foundational technology of the 21st century* *Tom Knight, MIT, SB3*

- Biology > Physics ($, staff, discoveries)
- Biology is more important than physics, as measured by its economic outputs, ethical implications, and effects on human welfare
- Alberta already *has* a vibrant bio-economy
- Well-positioned to become a global leader in synthetic biotechnologies *is we act quickly and decisively*

# Start education programs…

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 economy and advances in biomedicine and economic growth.

…the control and design of …d new organisms to solve a …energy, and environmental …solved using naturally …es. The inherently

QB3 and LBNL scientists occupy lab space in a building renovated in 1997 for biotech research, previously leased by Bayer, featuring large labs, viral suites, and tissue culture rooms. UCSF Mission Bay and numerous biotech firms are nearby.

# 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.

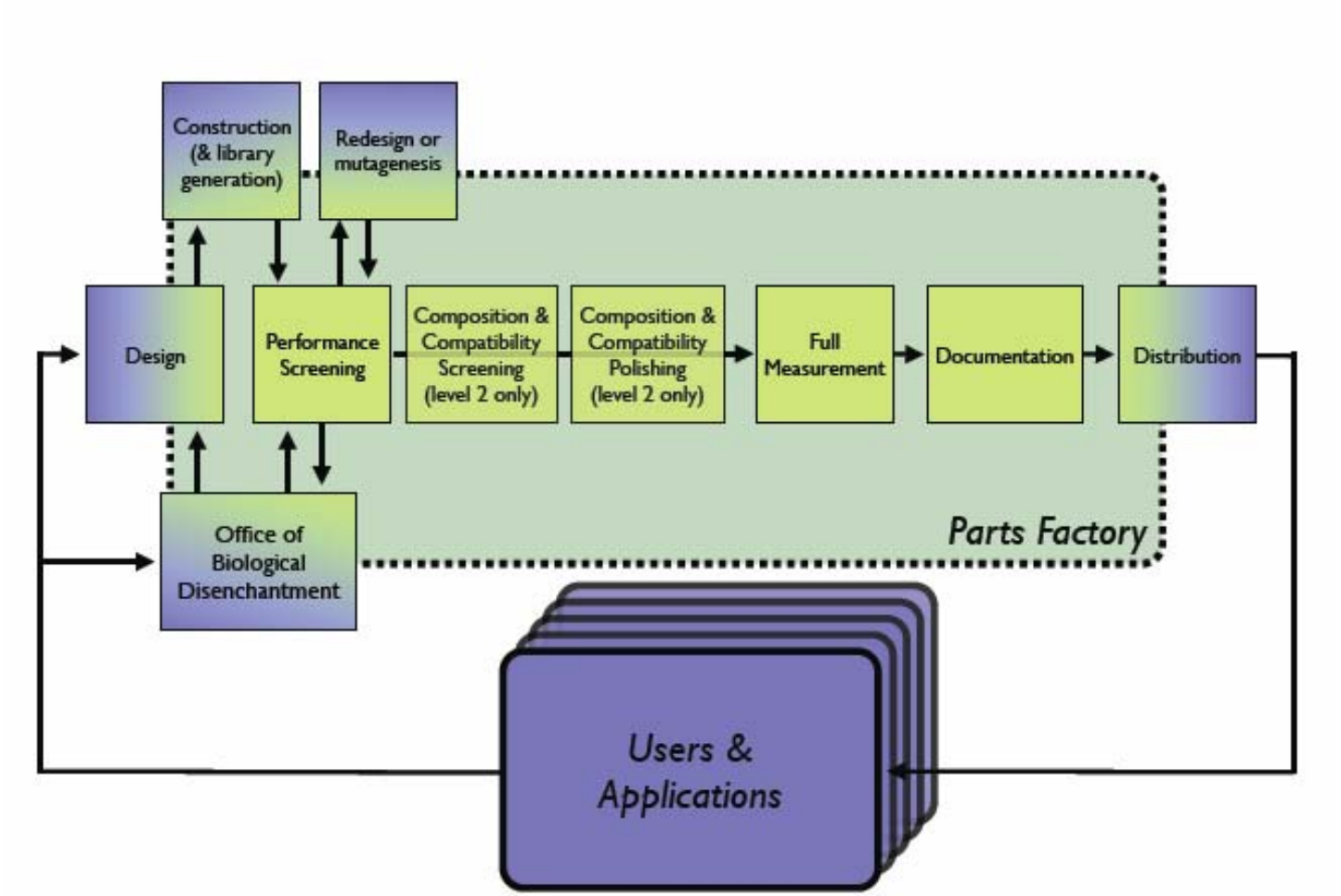
California Institute for
# Quantitative Biomedical Research


**2/1/2007 - BP awards $500 million bioenergy grant**
Global energy firm BP has selected UC Berkeley, in partnership with Lawrence Berkeley National Laboratory and the University of Illinois, to lead an unprecedented $500 million research effort to develop new sources of energy and reduce the impact of energy consumption on the environment. The funding will create the Energy Biosciences Institute, which initially will focus its research on biotechnology to produce biofuels. QB3 helped coordinate the research proposal and will help administer the project. More >


**6/26/2007 - Bay Area partnership to host DOE bioscience center**
The U.S. Department of Energy has announced the creation of a new bioenergy research center, with UC Berkeley and Lawrence Berkeley National Laboratory as two of its six collaborating institutions. The Joint BioEnergy Institute – to be headquartered in the East Bay and led by Jay Keasling – will receive approximately $125 million in DOE funding over five years. More >


**8/3/2006 - New center poised to transform biotech**
Aided by a $16 million NSF grant, QB3 has launched the Synthetic Biology Engineering Research Center at UC Berkeley, with collaborators at UC San Francisco, MIT, Harvard, and Prairie View A&M University. Researchers hope to make it as quick and easy to engineer biology as it now is to assemble microprocessors, hard drives, and memory chips into a computer. More >

# Build a bio-fab to support research community and next-gen companies



Technology
PUBLISHED BY MIT Review

Monday, April 09, 2007

# DNA Factories

## Cheaply churning out made-to-order DNA could revolutionize molecular biology.

By Emily Singer

# LS9, INC.

the renewable petroleum company™

AMYRIS
BIOTECHNOLOGIES

Realizing the Promise of Synthetic Biology

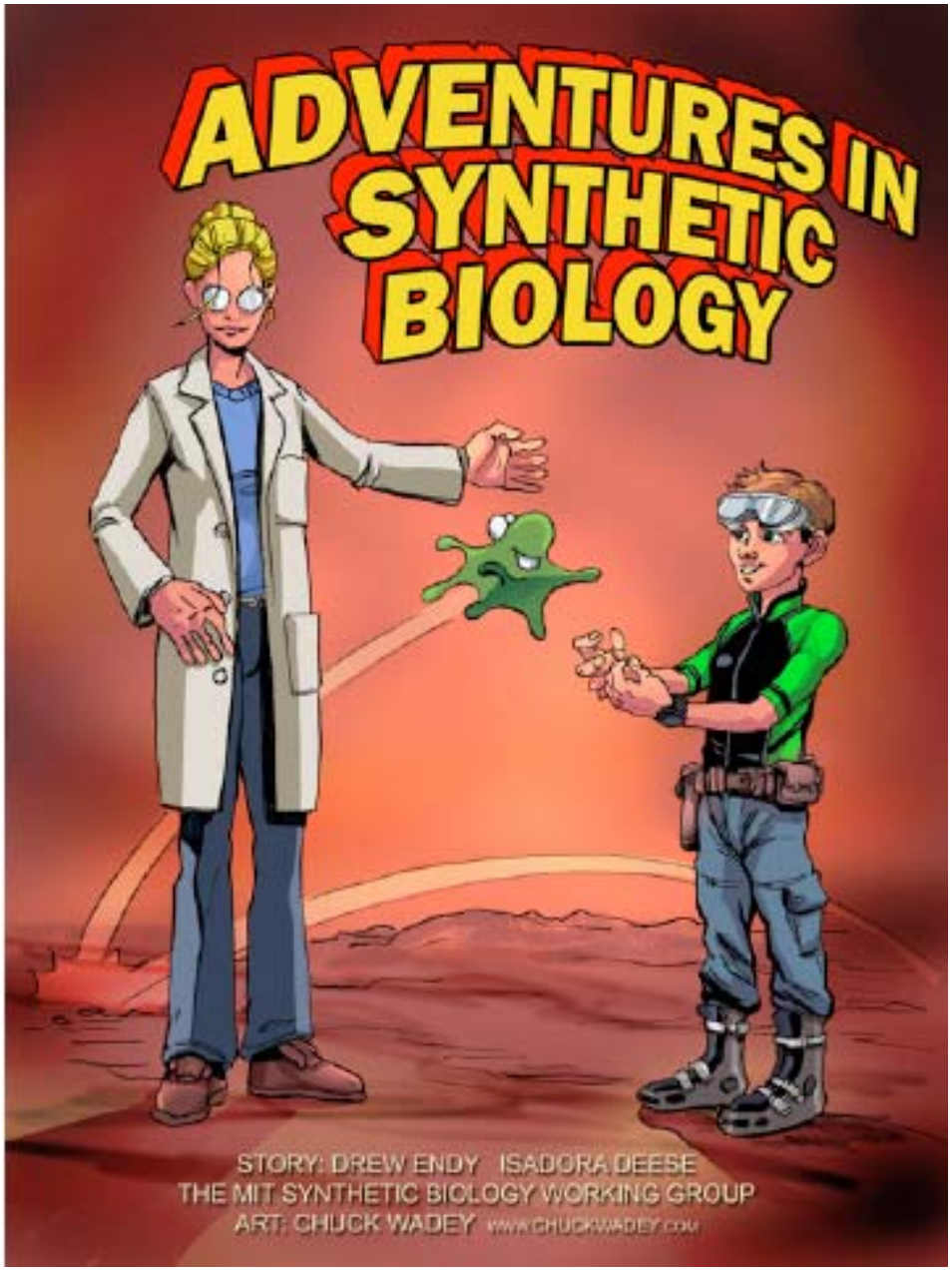
COMPANY PROFILE | TECHNOLOGY | CURRENT PROJECTS | NEWS | CAREERS

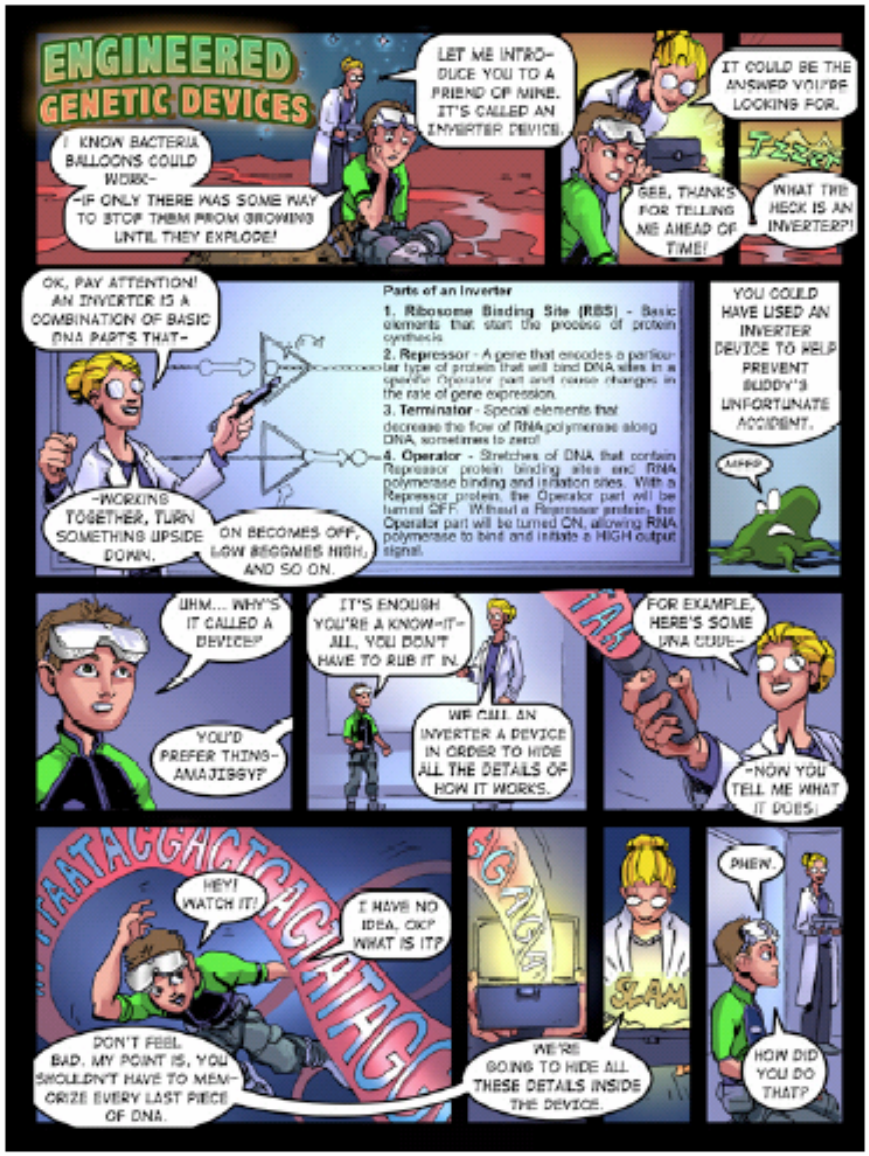
# Welcome

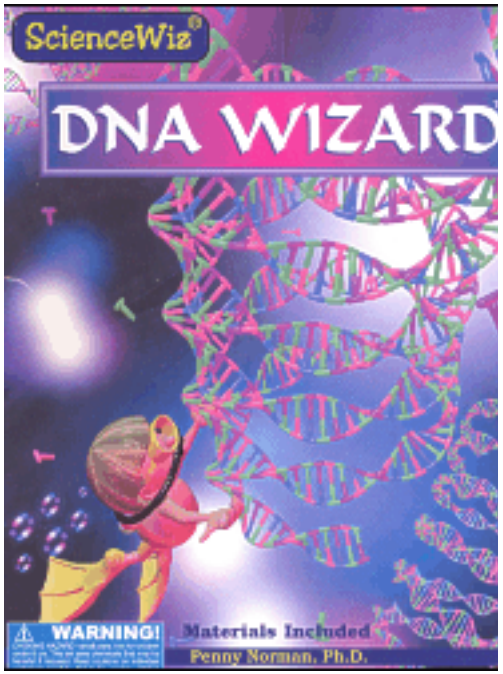
Amyris Biotechnologies is translating the promise of synthetic biology into solutions for real-world problems. Building on advances in molecular, cell and systems biology, we are engineering microbes capable of producing high-value compounds to address major global health and energy challenges. We are employing these living chemical factories to produce novel pharmaceuticals, renewable fuels, and specialty chemicals.

- *Applications (health, biofuels, bioproducts)
- Software: Metabolic and genomic design tools
- Hardware: Advanced synthesis hardware, biological test and measurement devices
- Ethics and social policy of synthetic biology
- Educational program development
- Next-generation biotechnology company development


MAY 3, 1982
$1.50
TIME
-.3%
INFLATION VANISHES!
At Least for A Month
COMPUTER GENERATION
A New Breed of Whiz Kids


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


ENGINEERED GENETIC DEVICES
I KNOW BACTERIA BALLOONS COULD WORK-
-IF ONLY THERE WAS SOME WAY TO STOP THEM FROM GROWING UNTIL THEY EXPLODE!
LET ME INTRODUCE YOU TO A FRIEND OF MINE. IT'S CALLED AN INVERTER DEVICE.
IT COULD BE THE ANSWER YOU'RE LOOKING FOR.
GEE, THANKS FOR TELLING ME AHEAD OF TIME!
WHAT THE HECK IS AN INVERTER?!
OK, PAY ATTENTION! AN INVERTER IS A COMBINATION OF BASIC DNA PARTS THAT-
-WORKING TOGETHER, TURN SOMETHING UPSIDE DOWN.
ON BECOMES OFF, LOW BECOMES HIGH, AND SO ON.
Parts of an Inverter
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 Operator part and cause changes in the rate of gene expression.
3. Terminator - Special elements that decrease the flow of RNA polymerase along DNA, sometimes to zero!
4. Operator - Stretches of DNA that contain Repressor protein binding sites and 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 signal.
YOU COULD HAVE USED AN INVERTER DEVICE TO HELP PREVENT BUDDY'S UNFORTUNATE ACCIDENT.
MMMF
UHM... WHY'S IT CALLED A DEVICE?
YOU'D PREFER THING-AMAJIBBY?
IT'S ENOUGH YOU'RE A KNOW-IT-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.
FOR EXAMPLE, HERE'S SOME DNA CODE-
-NOW YOU TELL ME WHAT IT DOES!
HEY! WATCH IT!
I HAVE NO IDEA. OK? WHAT IS IT?
DON'T FEEL BAD. MY POINT IS, YOU SHOULDN'T HAVE TO MEMORIZE EVERY LAST PIECE OF DNA.
WE'RE GOING TO HIDE ALL THESE DETAILS INSIDE THE DEVICE.
SLAM
PHEW.
HOW DID YOU DO THAT?





http://www.electrowiz.com/