Synthetic Biology

Risks, rewards, and opportunities

Andrew Hessel

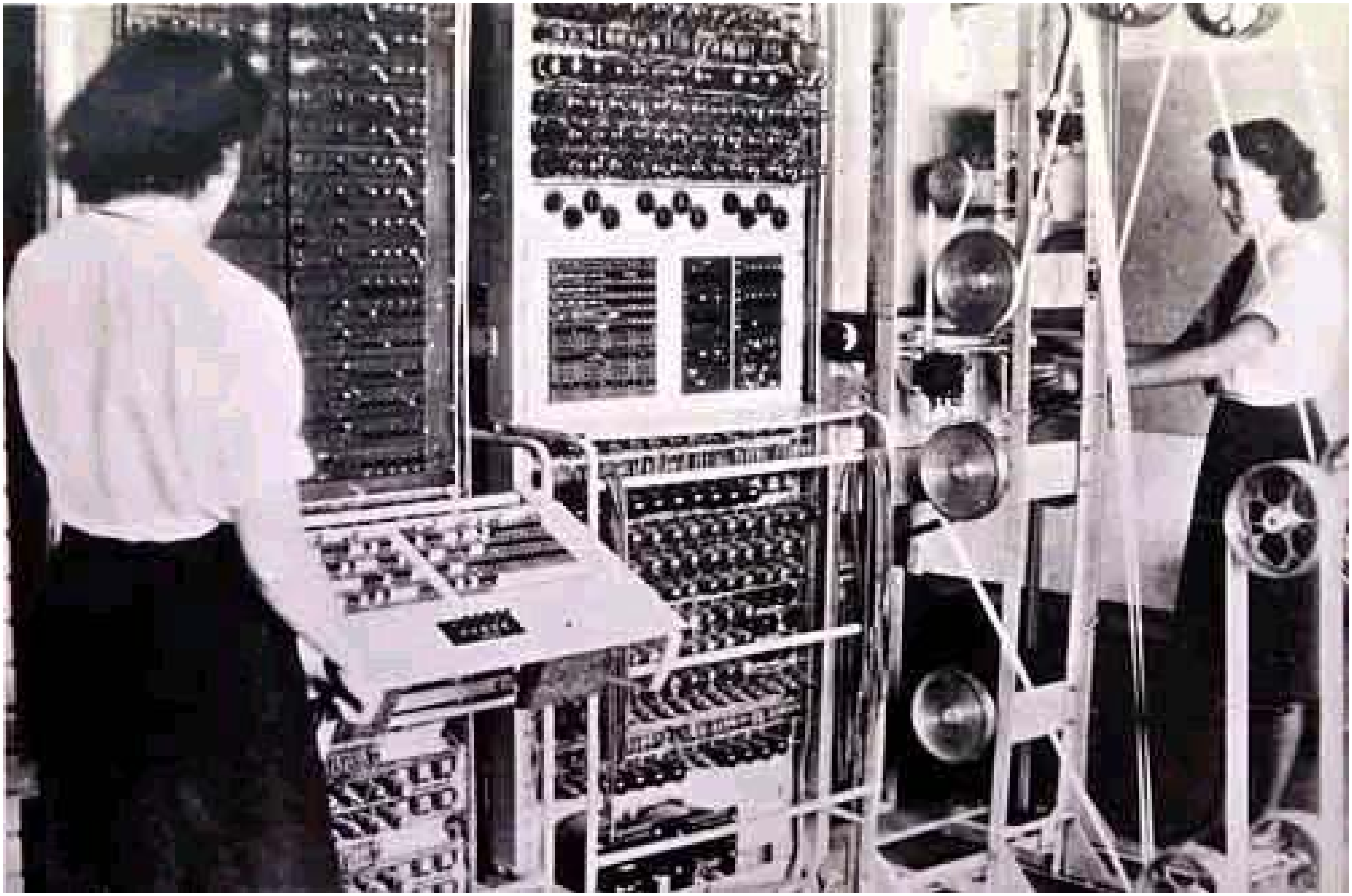
ahessel@gmail.com

Cross Cancer Institute, October 23 2007

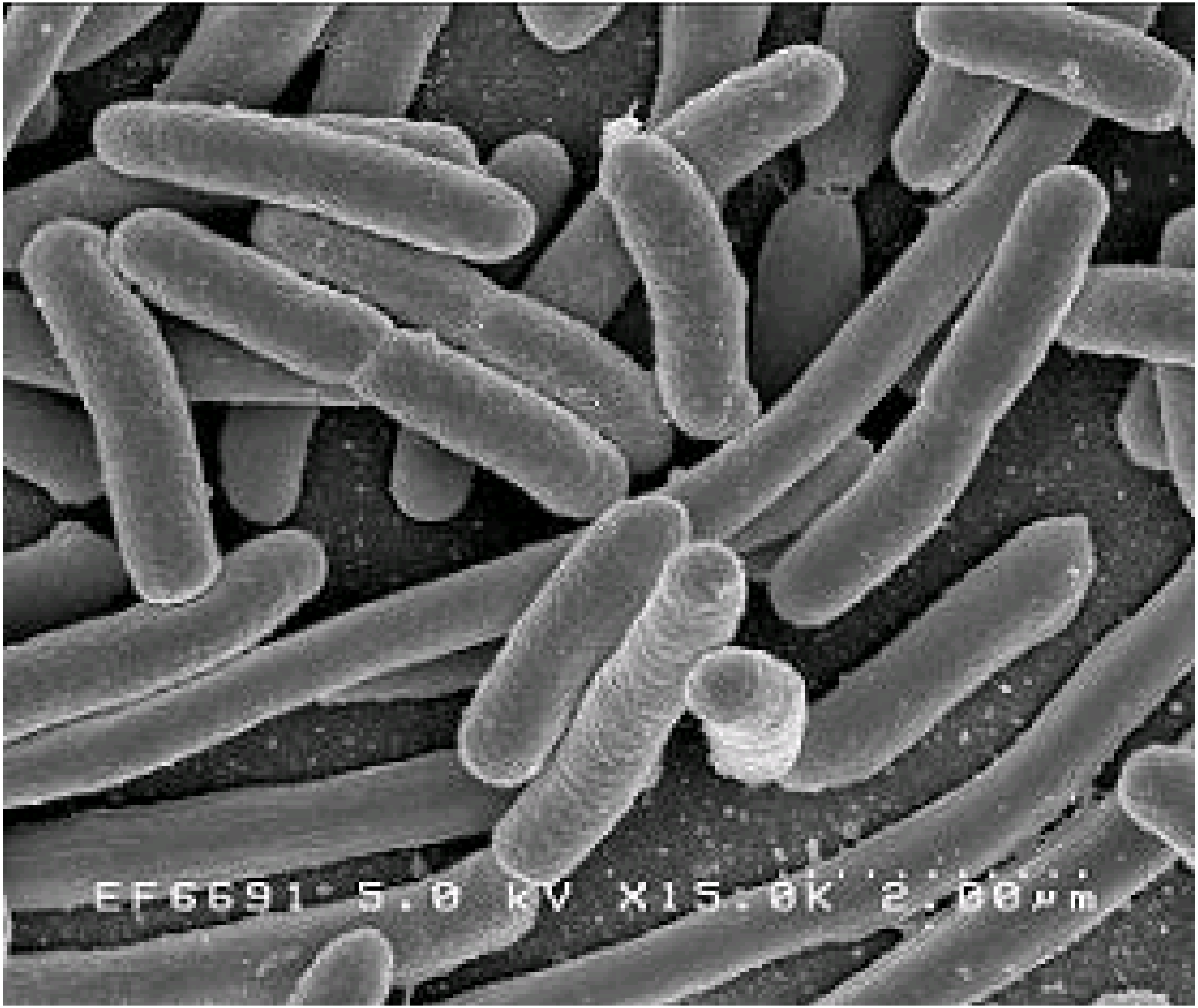
Synthetic biology is a basket of technologies that facilitate the engineering of living organisms

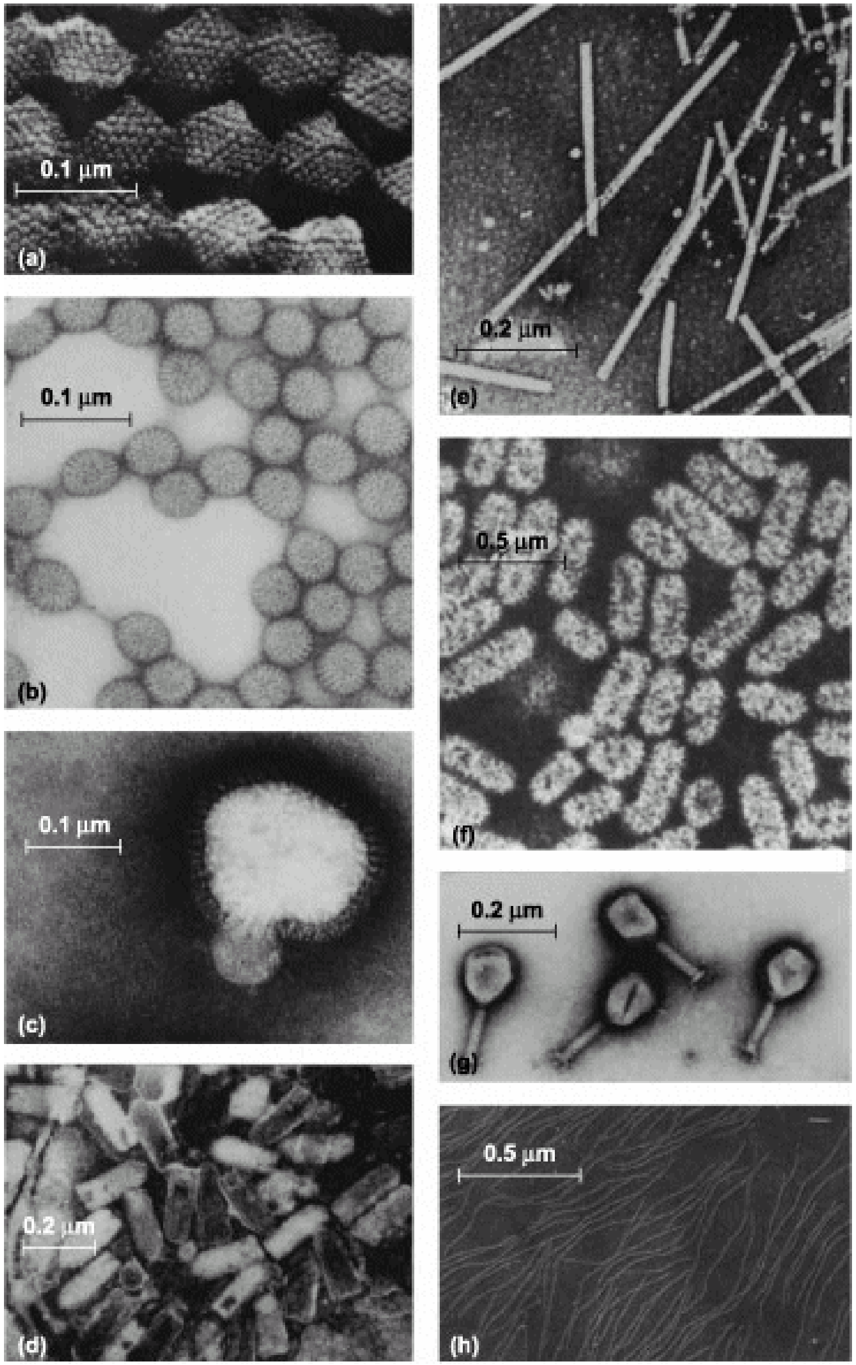
Potentially the single most important technology of this century…


microelectronics group
Lucent Technologies
Bell Labs Innovations
A replica of the first transistor,
invented at Bell Labs,
December 23, 1947
50 Years and Counting...




WARNING


EF6691 5.0 kV X15.0K 2.00µm



http://content.answers.com/main/content/img/McGrawHill/Encyclopedia/images/CE733500FG0010.gif

Bits (0s,1s) encode information for digital electronic processors (computers)

DNA encodes information for analog biochemical processors (cells)

DNA is source code for biological systems

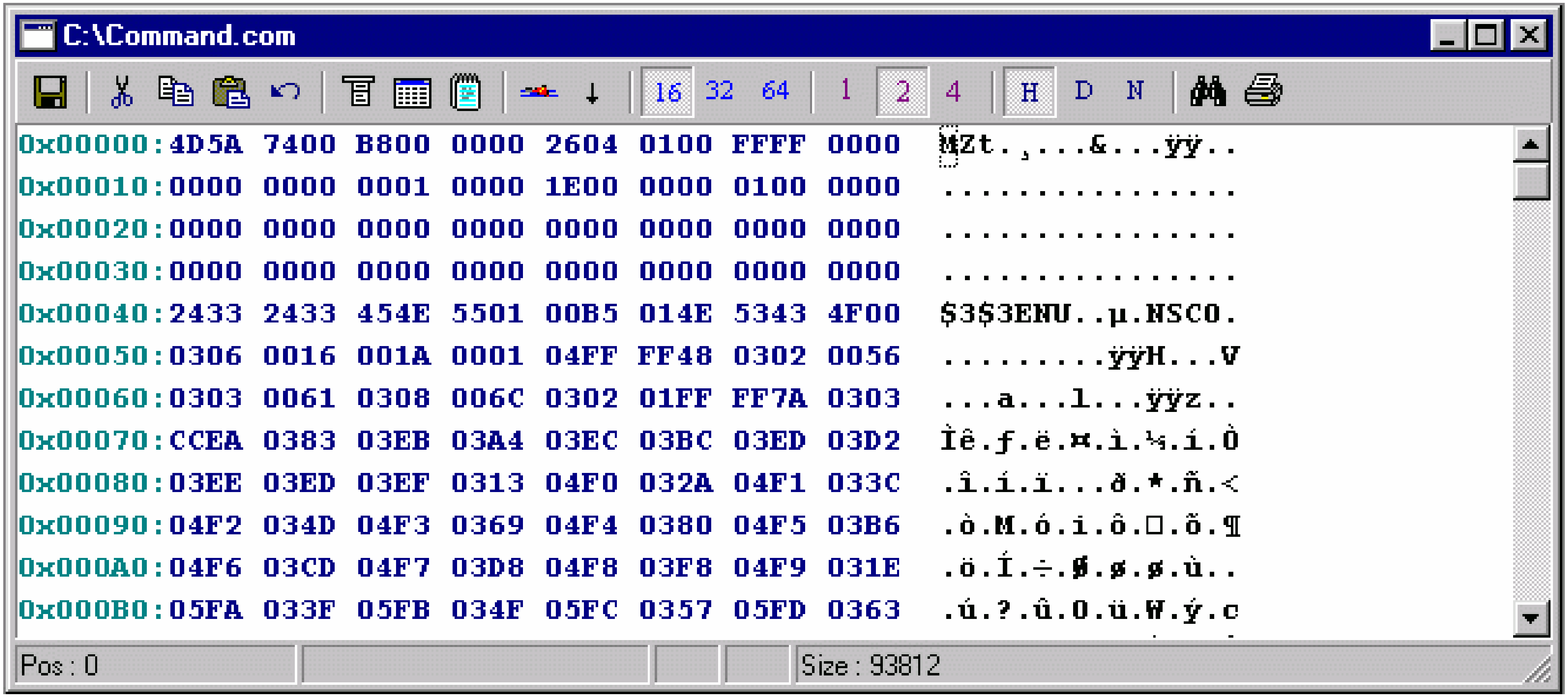
Change the code, change metabolism

Genomes are special programs that encode:

- Instructions for biochemical processors
- Machinery to duplicate the processor and install the program onto processors

Equivalent in computing not to an operating system but to all the software it would take to run a production line at Apple or Dell Inc.


danielg 072006 - S3is


C:\Command.com
16 32 64 1 2 4 H D N
0x00000:4D5A 7400 B800 0000 2604 0100 FFFF 0000
0x00010:0000 0000 0001 0000 1E00 0000 0100 0000
0x00020:0000 0000 0000 0000 0000 0000 0000 0000
0x00030:0000 0000 0000 0000 0000 0000 0000 0000
0x00040:2433 2433 454E 5501 00B5 014E 5343 4F00
0x00050:0306 0016 001A 0001 04FF FF48 0302 0056
0x00060:0303 0061 0308 006C 0302 01FF FF7A 0303
0x00070:CCEA 0383 03EB 03A4 03EC 03BC 03ED 03D2
0x00080:03EE 03ED 03EF 0313 04F0 032A 04F1 033C
0x00090:04F2 034D 04F3 0369 04F4 0380 04F5 03B6
0x000A0:04F6 03CD 04F7 03D8 04F8 03F8 04F9 031E
0x000B0:05FA 033F 05FB 034F 05FC 0357 05FD 0363
Pos : 0
Size : 93812

http://www.colorado.edu/MCDB/MCDB1111/intrographics/bacterial%20chromosome.jpg

http://academy.asd20.org/kadets/lundberg/ethics/images/chromosomes.jpg

ATG-TCA-AAT-AAA-AGT-AAT-GAT-AAT-GGC-AGA-GCA-TAT-GAG-TTT-GCA-TTT-ATA-AAT-GAA-

TTA-GGA-CGC-ATT-GCA-ACT-CAA-AAT-CAG-AAT-ATA-AAT-ATC-GAA-AAG-AAT-TCT-AGC-TAT-

TAC-GTA-GTT-GAG-AAA-TCT-TGG-AGT-ACA-TTA-TCG-GAT-CTT-GAA-AAA-GAA-AAA-TAT-ACA-

AAA-AGT-GCA-ATT-GCT-GGT-ATC-AAT-CTT-ATA-ACA-AGC-TTA-GAG-CCA-ATA-ATA-GAA-GAT-

GGT-AAT-GGT-GTA-TTA-AAC-TTA-AAA-ATA-CAA-GCT-GAT-AAT-AAA-GGT-GAA-TTA-GGC-GAT-

ATT-AGA-GAT-ATT-TTA-ATT-CAA-AGA-GAA-AAT-ATT-AAT-TGG-GAA-ATT-GGT-TTA-AGT-TTA-

AAA-CAT-AAT-CAT-TTT-GCT-GTG-AAA-CAT-AGT-CGT-TTA-TCA-CAT-AAA-ATT-GAT-TTT-TCA-

GAA-AAA-TGG-TTC-CAA-TTA-CCT-TCT-TCT-CAA-AAT-TAT-TGG-GAT-AAT-ATA-CTC-CCT-ATT-

TTT-GAG-AAA-TTA-GAA-ATT-TAT-AAA-AAA-GAT-AAA-ATA-AAA-TGG-AGA-GAG-TTA-TCT-AAT-

AAA-GAA-GAT-TGC-ATT-TAT-TAT-CCC-ATA-CTT-AAA-TCA-TTT-ATA-GCA-GAA-ATT-AAA-GAA-

AAG-TAT-GAT-AAA-TAT-AAT-TCT-ATT-GTT-CCA-CAG-AGA-ATG-GTT-GAA-TAT-TTA-CTT-GGA-

TAT-TTT-GAT-TTC-TAT-AAA-ATC-ATA-AGT-CAA-GAT-AAT-AAG-AAA-CTA-ACA-TCT-ATT-CAA-

TCA-TTT-AAT-TTA-CGT-GGA-ACA-CTA-AAT-AAA-CCC-TCT-AAA-AAA-CGA-AAG-GCA-GAC-ATT-

TTT-ATA-CCT-GTA-GCT-AAT-TTA-CCA-ACT-AGA-ATC-ATT-GAT-ATA-GAT-TTT-AAG-CCA-AAT-

AGT-AAA-AAC-ACG-GTT-GAA-TTA-TAT-TTA-GAT-AAA-GGA-TGG-CAA-TTT-AGT-TTT-AGA-ATA-

CAT-AAT-GCT-TCT-ACT-ATT-ATT-GAA-CCG-AGC-TTG-AAA-TTT-GAT-ATA-AAA-CTT-ATT-GGT-

GTT-CCT-GCC-ACA-ATA-ATT-TGT-TTA-GAG-ACC-CCT-TGG-GAA-GAA-TGA

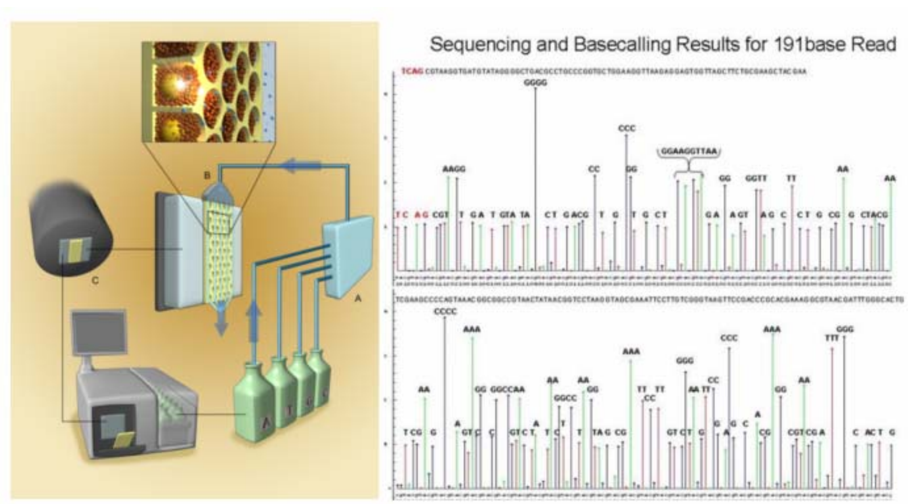
Nobel foundation

1980
500 bp/day (manual)

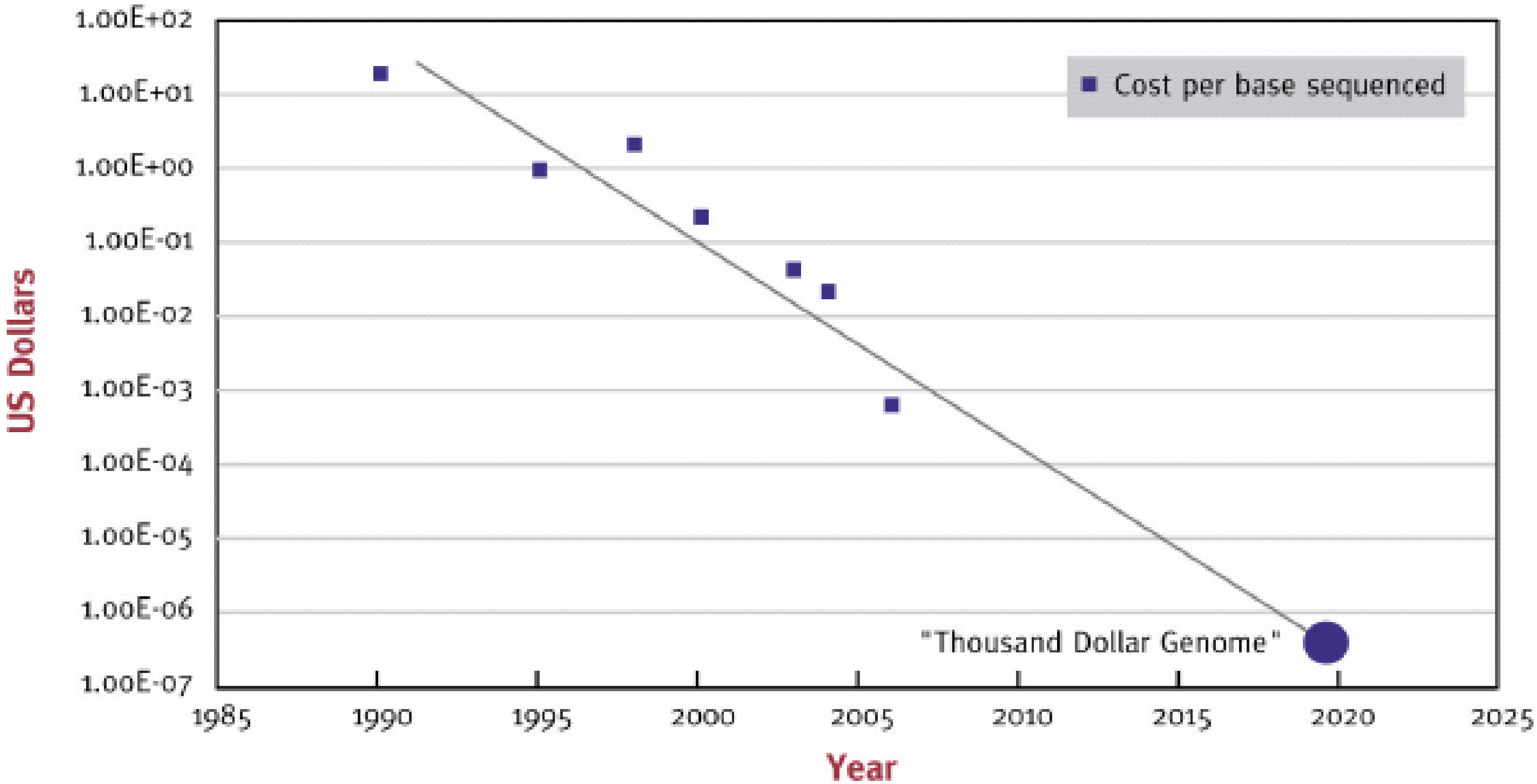
1987
36,000 bp/day (semi-auto)

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

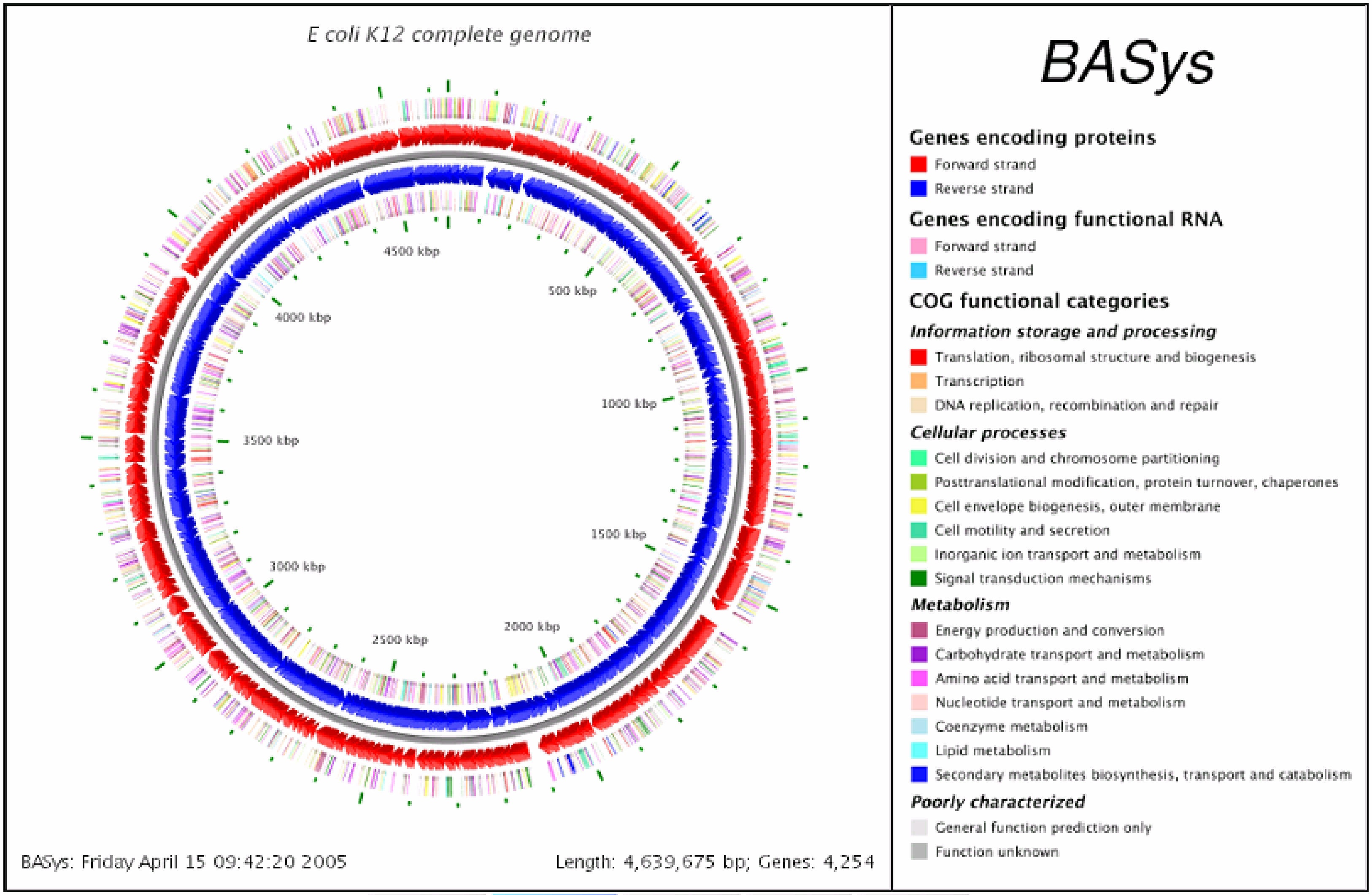
1998
500,000 bp/day (automatic)

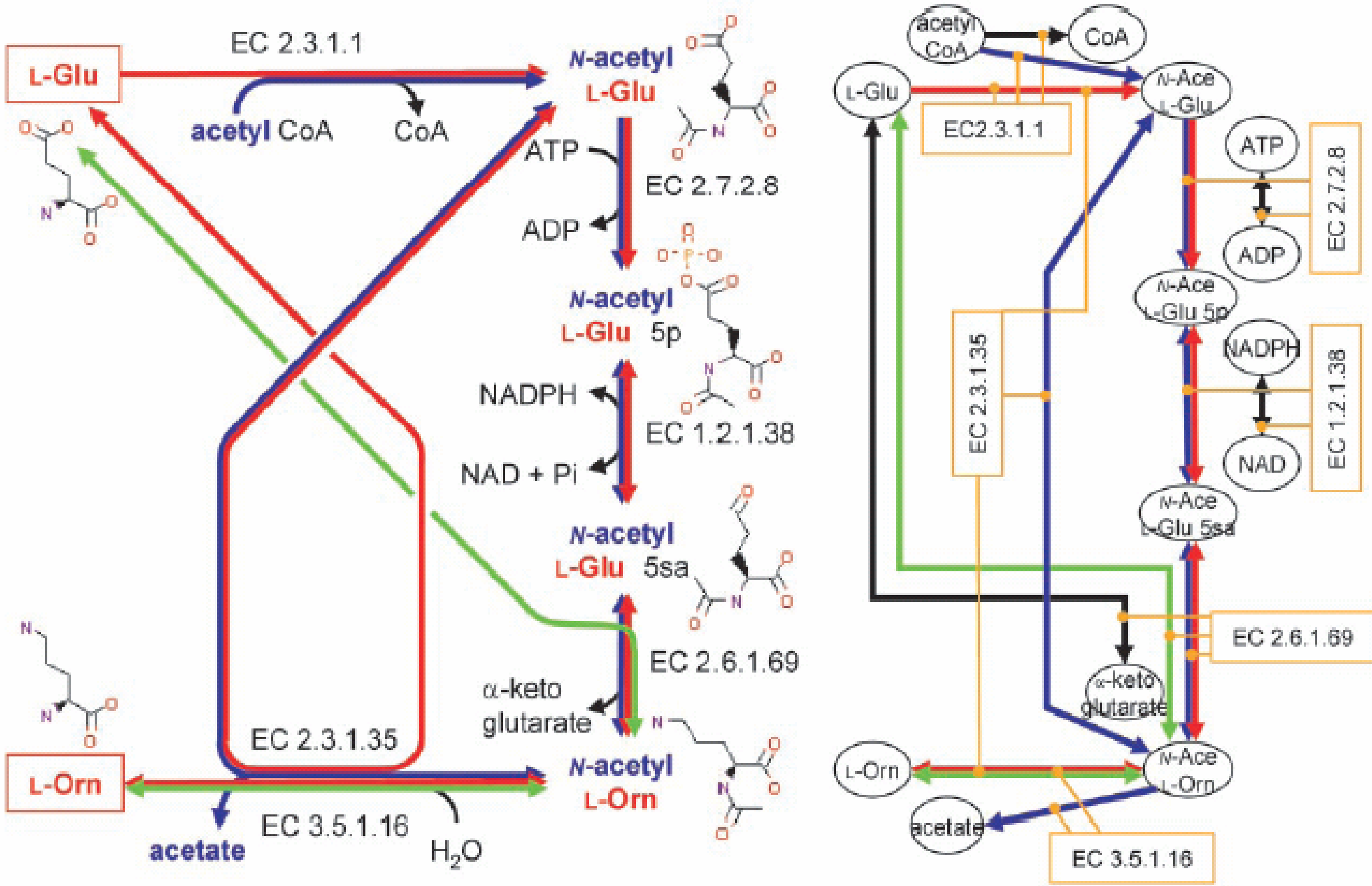


2007 – Sequencing by Synthesis
1GB bp/day (automatic)

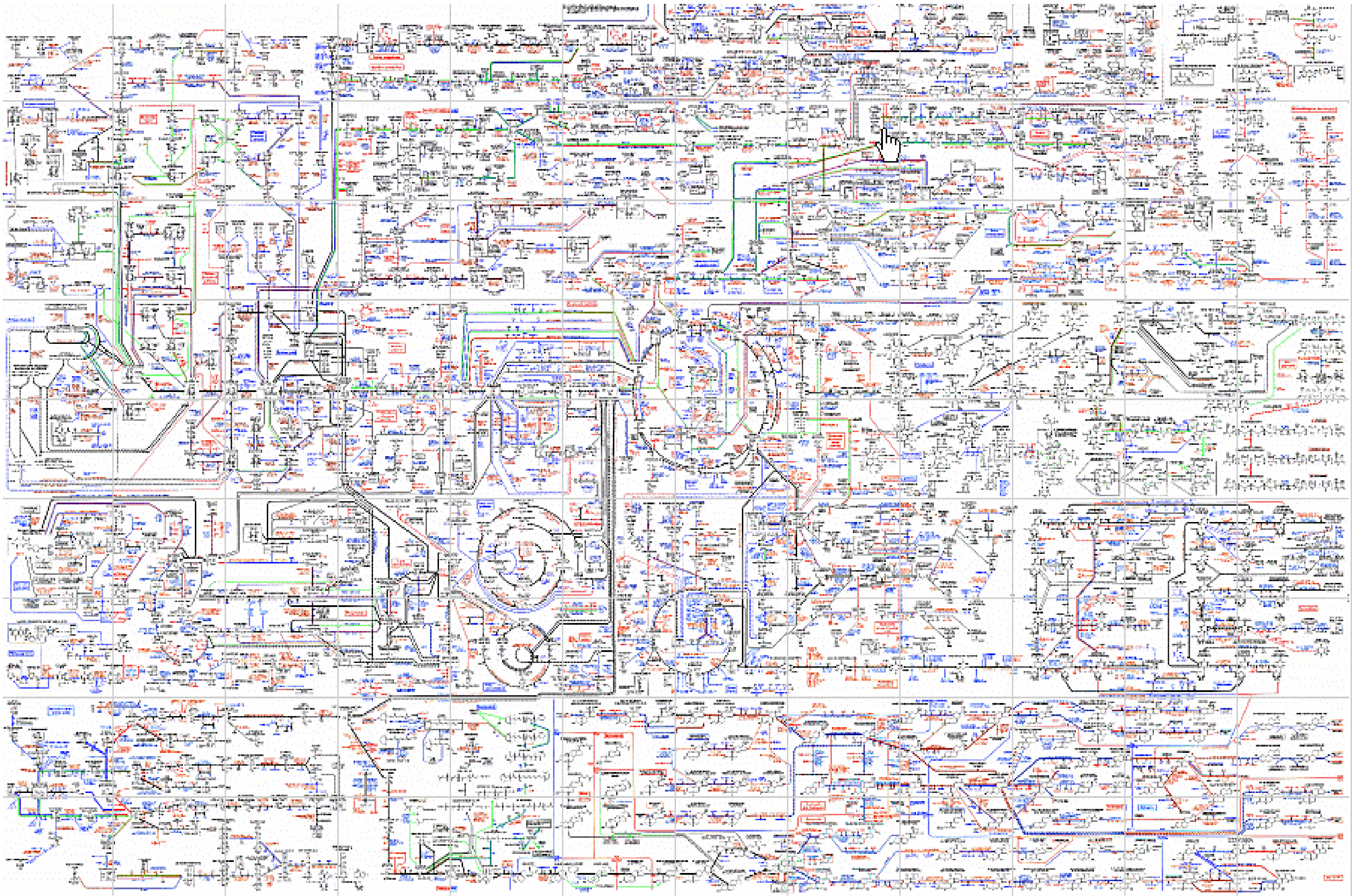


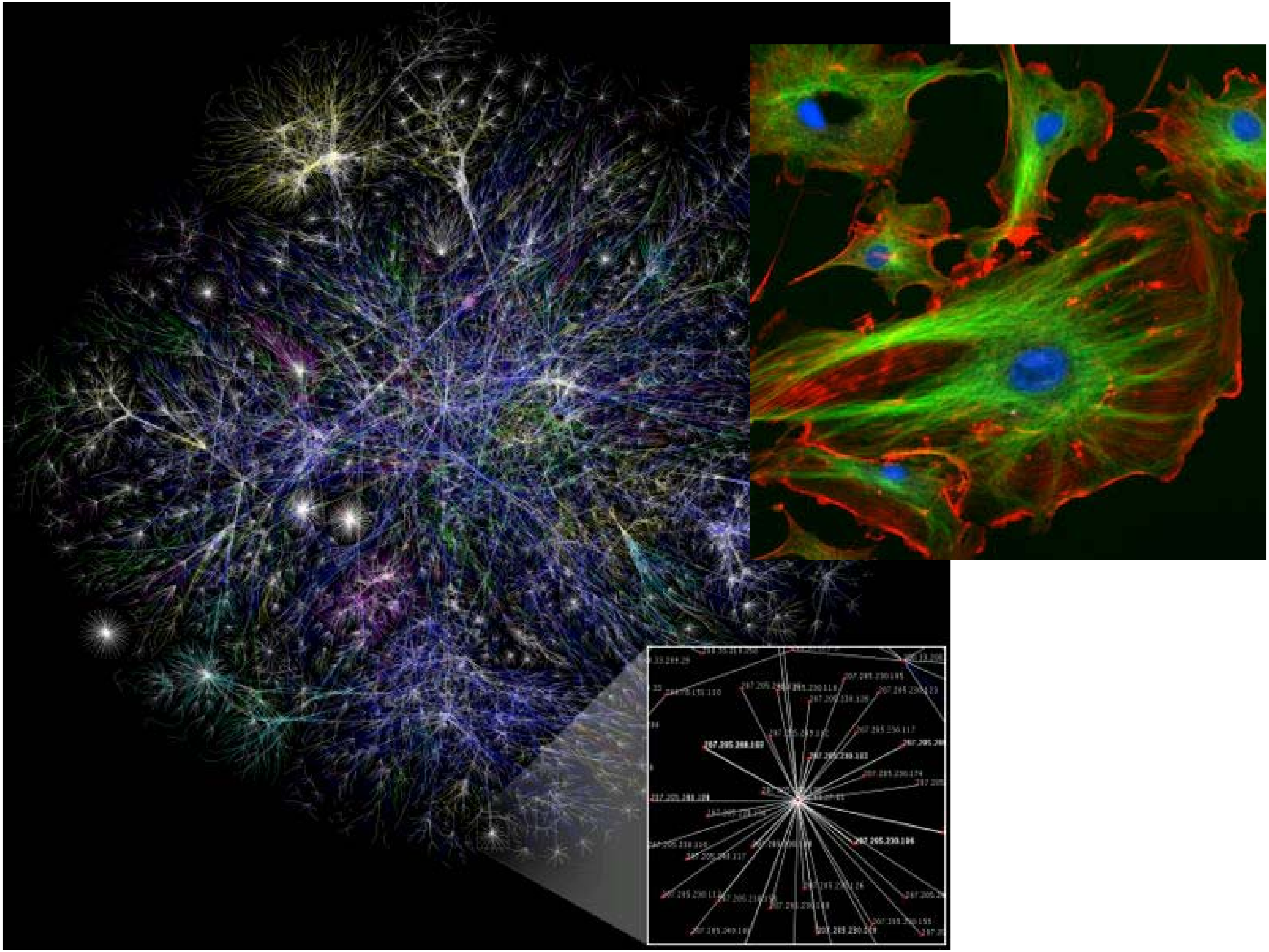
Source: R. Carlson, Bio-era

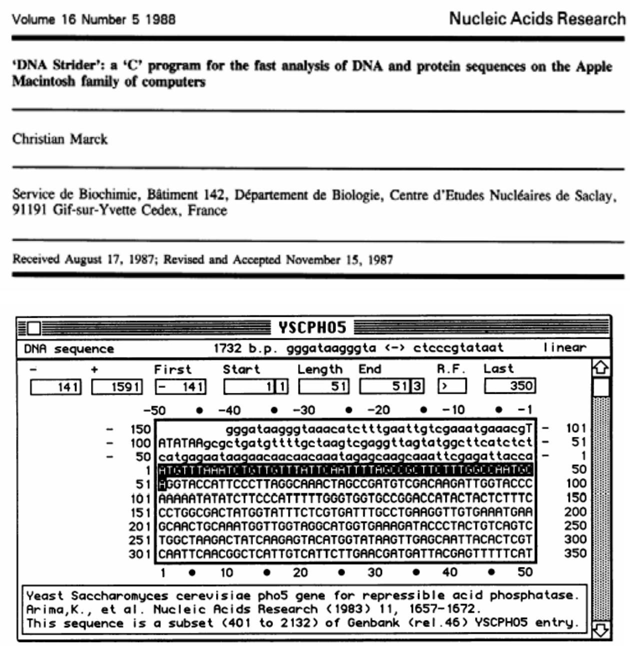

E coli K12 complete genome
4500 kbp
500 kbp
4000 kbp
1000 kbp
3500 kbp
1500 kbp
3000 kbp
2000 kbp
2500 kbp
BASys: Friday April 15 09:42:20 2005
Length: 4,639,675 bp; Genes: 4,254
BASys
Genes encoding proteins
Forward strand
Reverse strand
Genes encoding functional RNA
Forward strand
Reverse strand
COG functional categories
Information storage and processing
Translation, ribosomal structure and biogenesis
Transcription
DNA replication, recombination and repair
Cellular processes
Cell division and chromosome partitioning
Posttranslational modification, protein turnover, chaperones
Cell envelope biogenesis, outer membrane
Cell motility and secretion
Inorganic ion transport and metabolism
Signal transduction mechanisms
Metabolism
Energy production and conversion
Carbohydrate transport and metabolism
Amino acid transport and metabolism
Nucleotide transport and metabolism
Coenzyme metabolism
Lipid metabolism
Secondary metabolites biosynthesis, transport and catabolism
Poorly characterized
General function prediction only
Function unknown



Ornithine biosynthesis





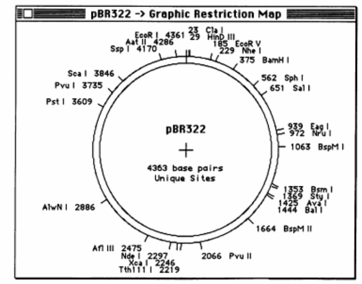

Volume 16 Number 5 1988 Nucleic Acids Research

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

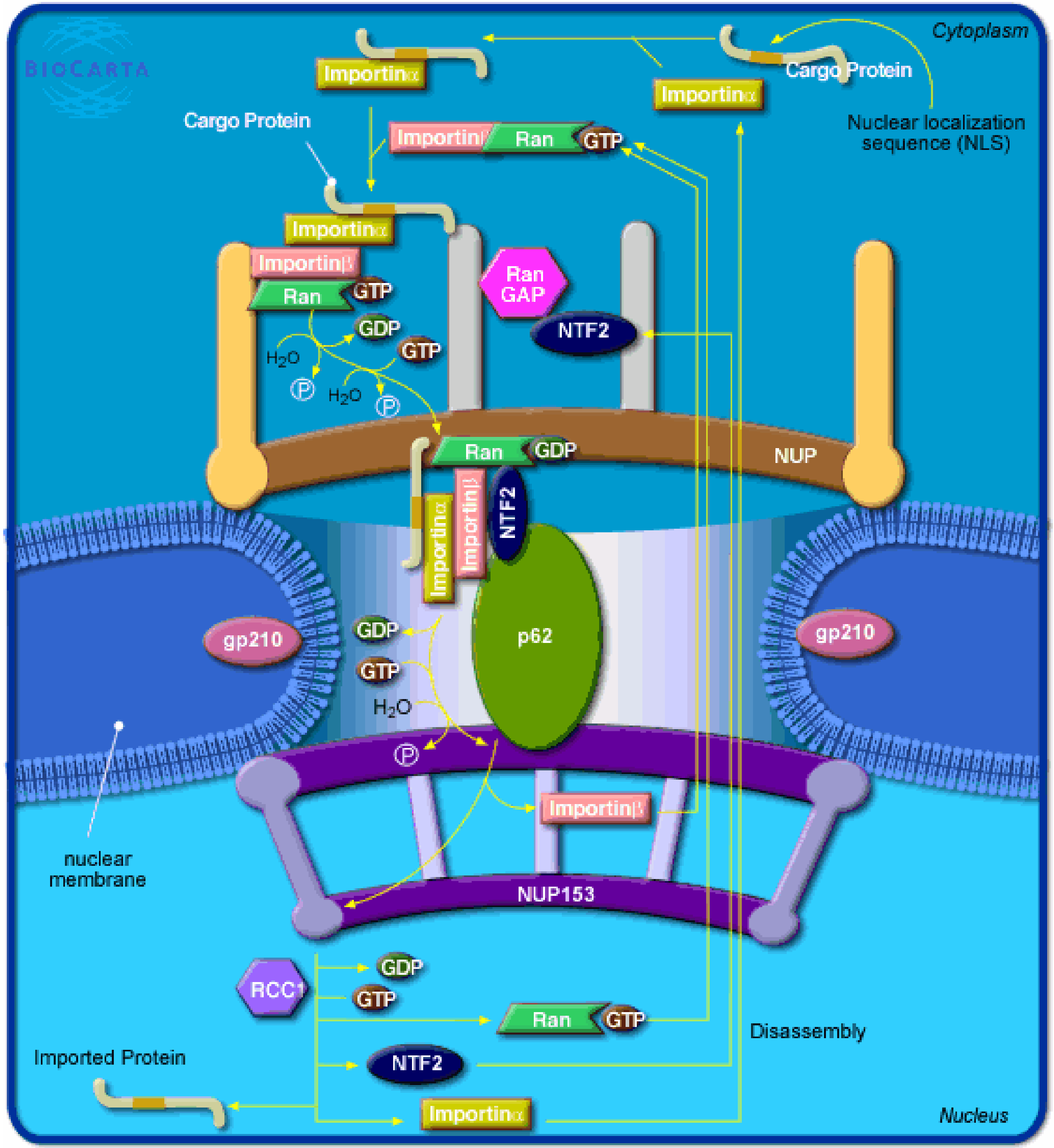
Christian Marck

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


Cytoplasm
Importinα
Cargo Protein
Importinα
Nuclear localization
sequence (NLS)
Cargo Protein
Importinβ
Ran
GTP
Importinα
Importinβ
Ran
GTP
Ran
GAP
GDP
GTP
NTF2
H₂O
Ⓟ
H₂O
Ⓟ
Ran
GDP
NUP
Importinα
Importinβ
NTF2
p62
gp210
gp210
GDP
GTP
H₂O
Ⓟ
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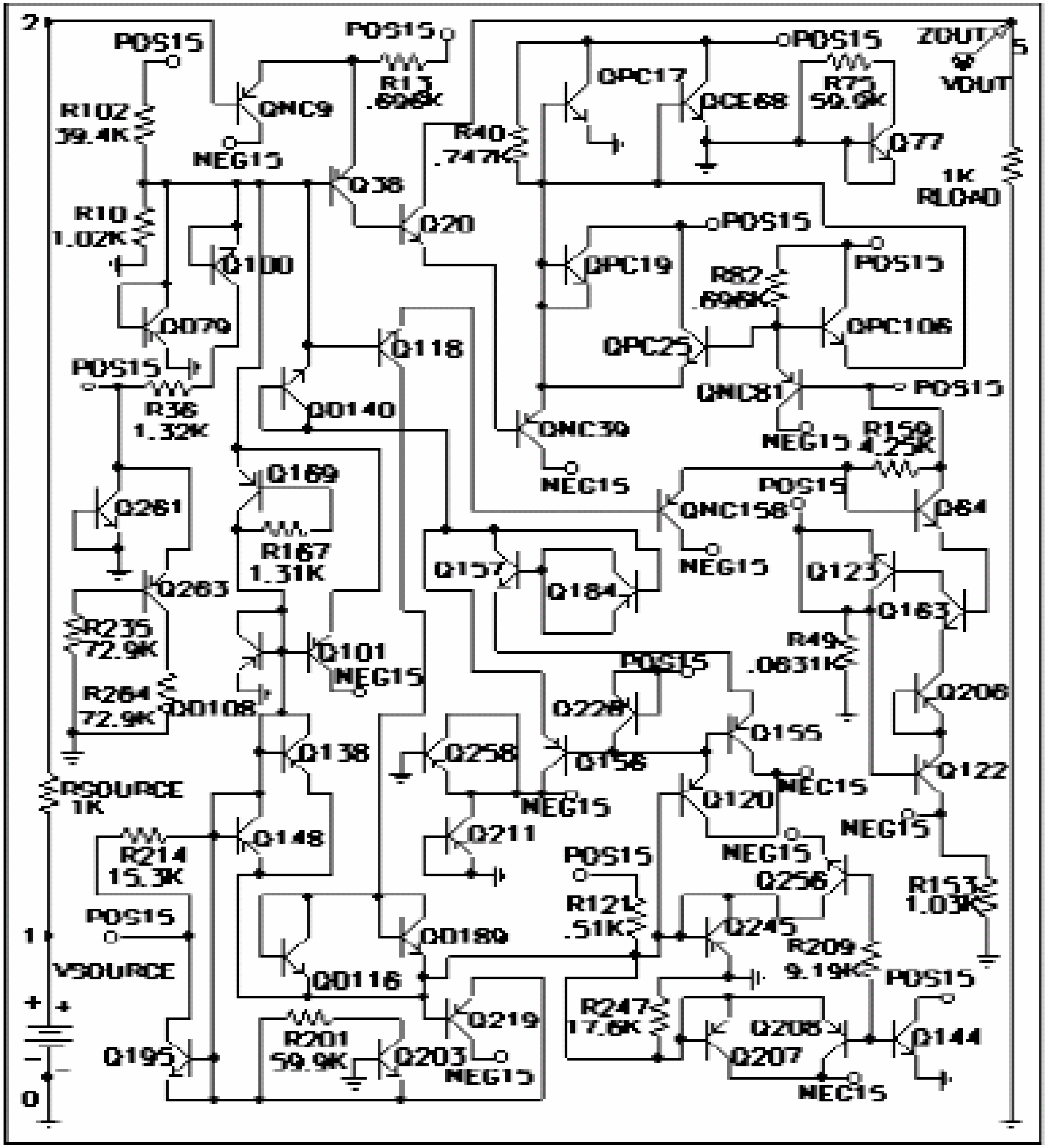
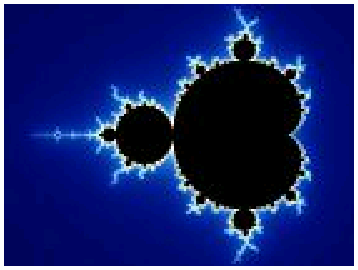
nuclear
membrane
NUP153
RCC1
GDP
GTP
Ran
GTP
Disassembly
Imported Protein
NTF2
Importinα
Nucleus

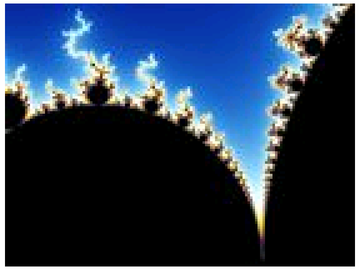


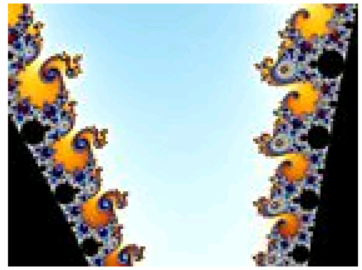
J.R. Koza et al.
Automatic creation of computer programs for designing electrical circuits using genetic programming.

http://www.genetic-programming.com/jkpdf/acdm1998.pdf

$$M = \left\{ c \in \mathbb{C} : \sup_{n \in \mathbb{N}} |f_c^n(0)| < \infty \right\}.$$


Start


Step 1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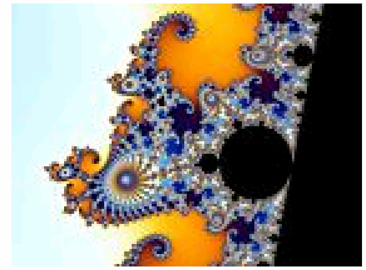
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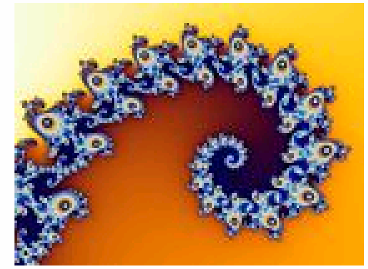
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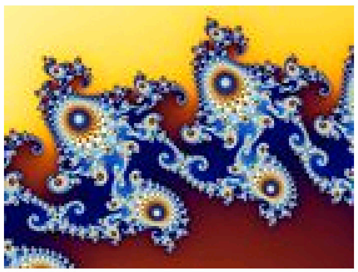
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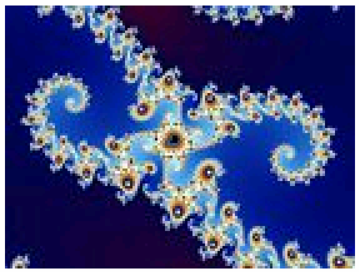
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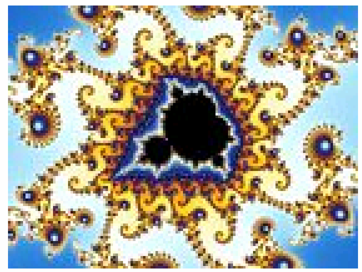
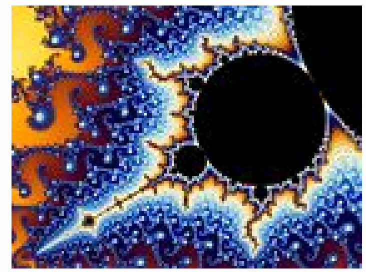
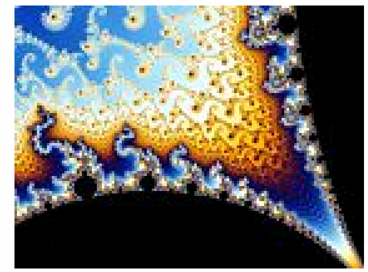
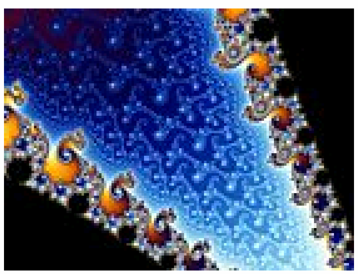

Step 7


Step 8


Step 9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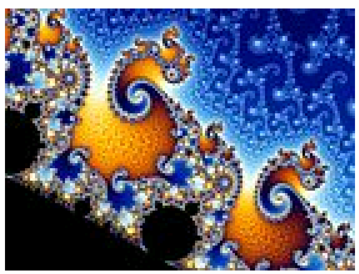
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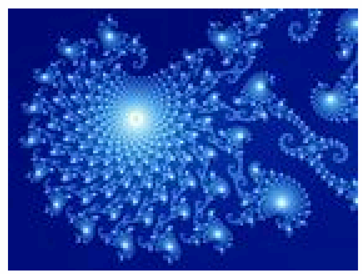
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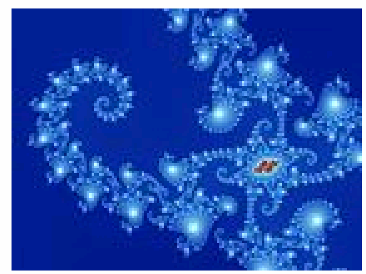
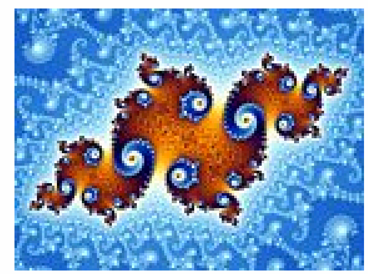
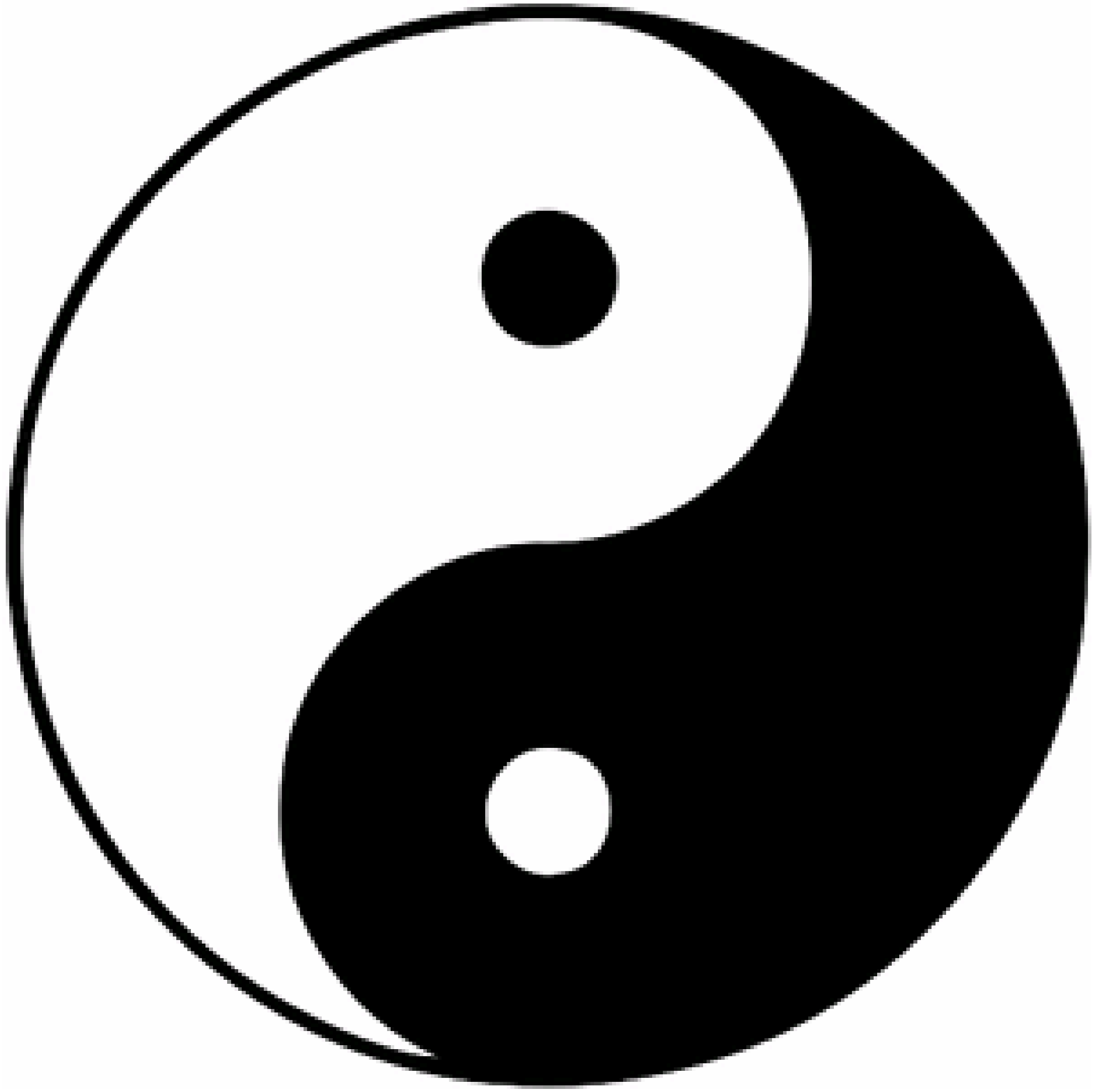

Step 13


Step 14

Reduction | Complexity



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

Genetic “Engineering”

Writing code

Proc. Nat. Acad. Sci. USA
Vol. 69, No. 10, pp. 2904–2909, October 1972

Biochemical Method for Inserting New Genetic Information into DNA of Simian Virus 40: Circular SV40 DNA Molecules Containing Lambda Phage Genes and the Galactose Operon of *Escherichia coli*

(molecular hybrids/DNA joining/viral transformation/genetic transfer)

DAVID A. JACKSON*, ROBERT H. SYMONS†, AND PAUL BERG

Department of Biochemistry, Stanford University Medical Center, Stanford, California 94305

Contributed by Paul Berg, July 31, 1972

Proc. Nat. Acad. Sci. USA
Vol. 70, No. 11, pp. 3240–3244, November 1973

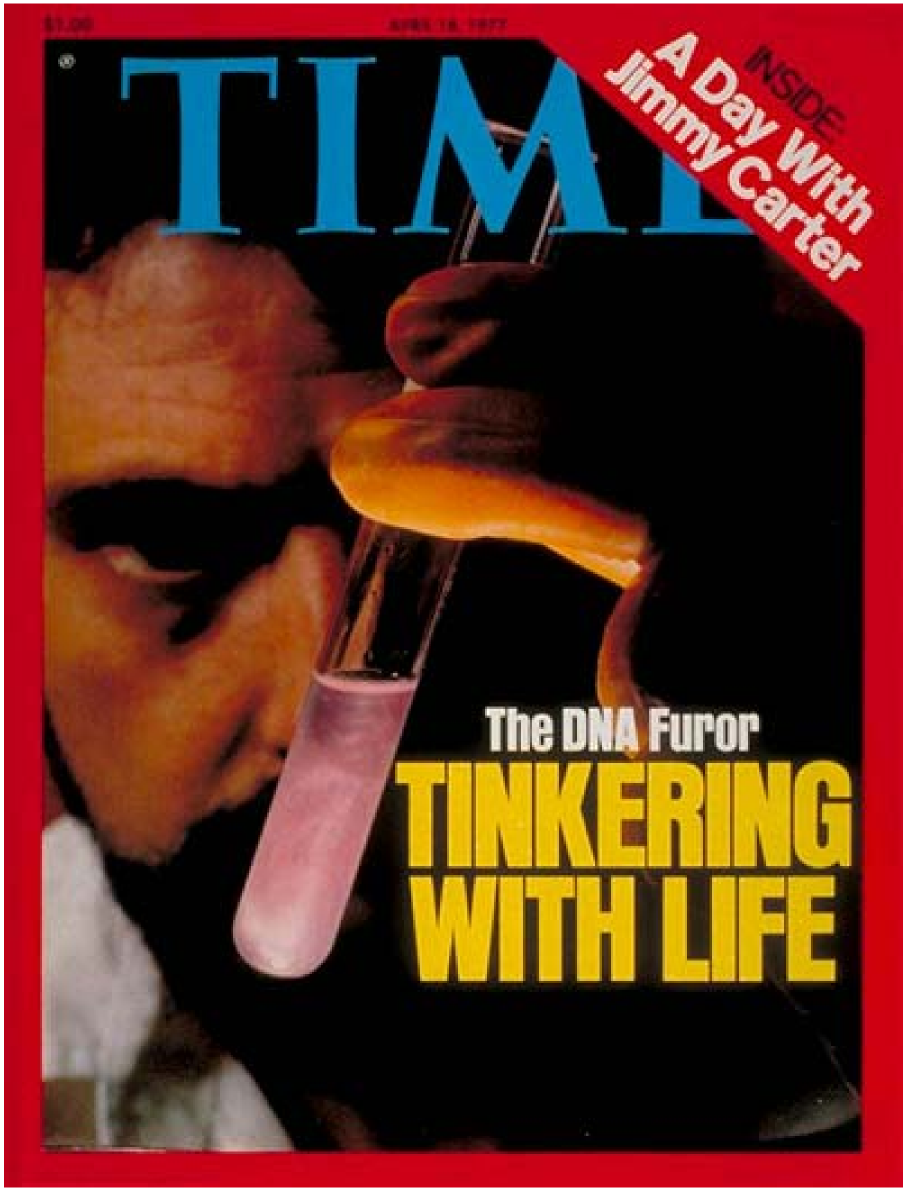
Construction of Biologically Functional Bacterial Plasmids *In Vitro*

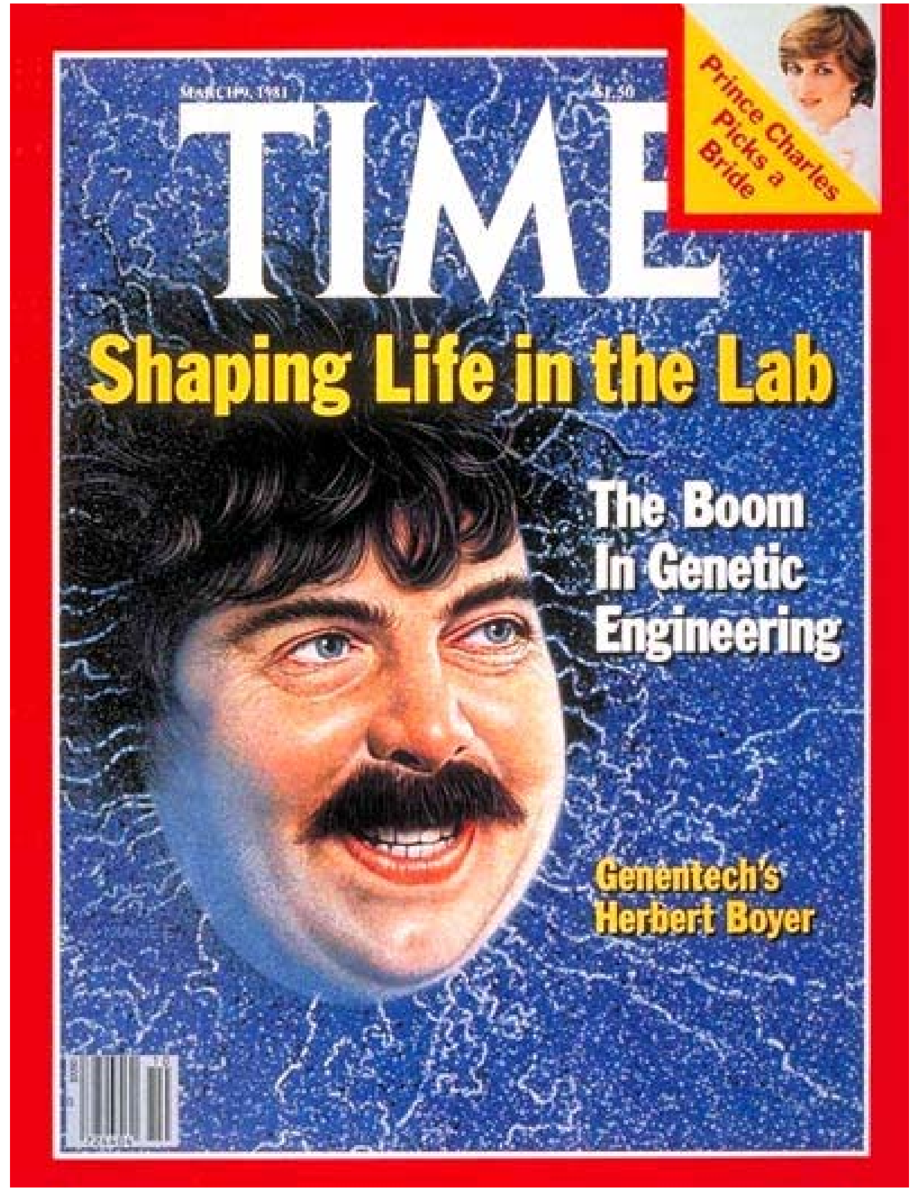
(R factor/restriction enzyme/transformation/endonuclease/antibiotic resistance)

STANLEY N. COHEN*, ANNIE C. Y. CHANG*, HERBERT W. BOYER†, AND ROBERT B. HELLING†

* Department of Medicine, Stanford University School of Medicine, Stanford, California 94305; and † Department of Microbiology, University of California at San Francisco, San Francisco, Calif. 94122

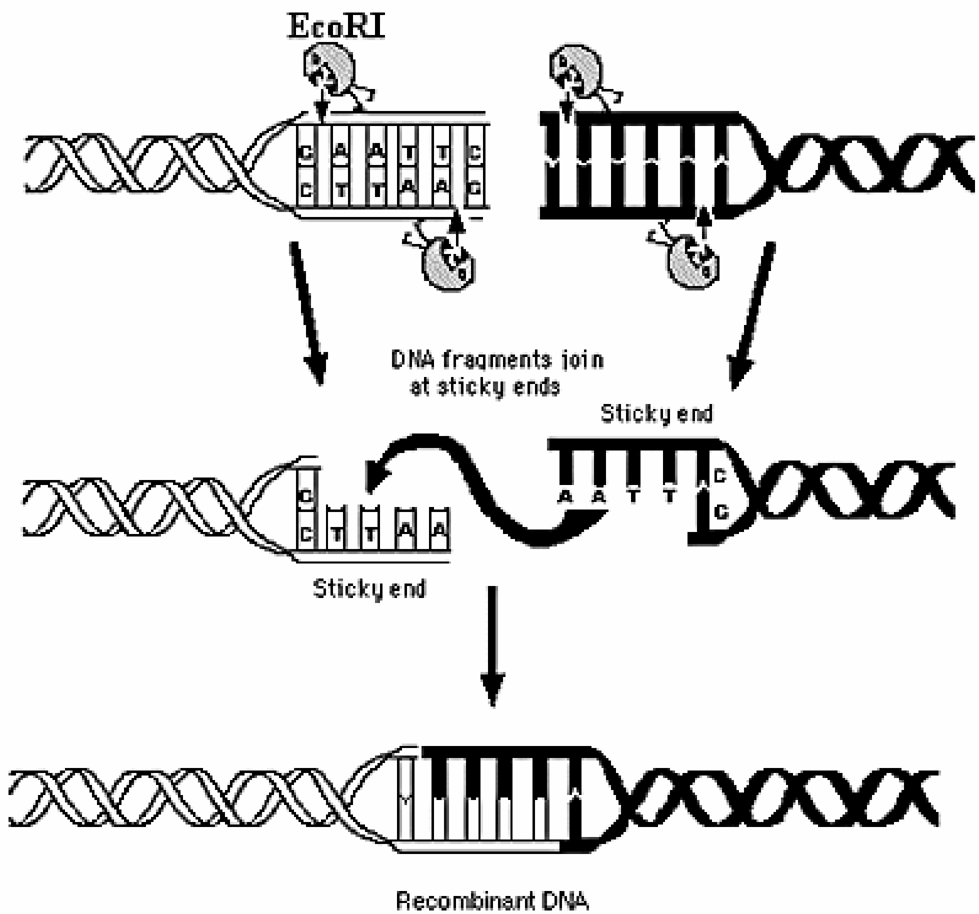
Communicated by Norman Davidson, July 18, 1973


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

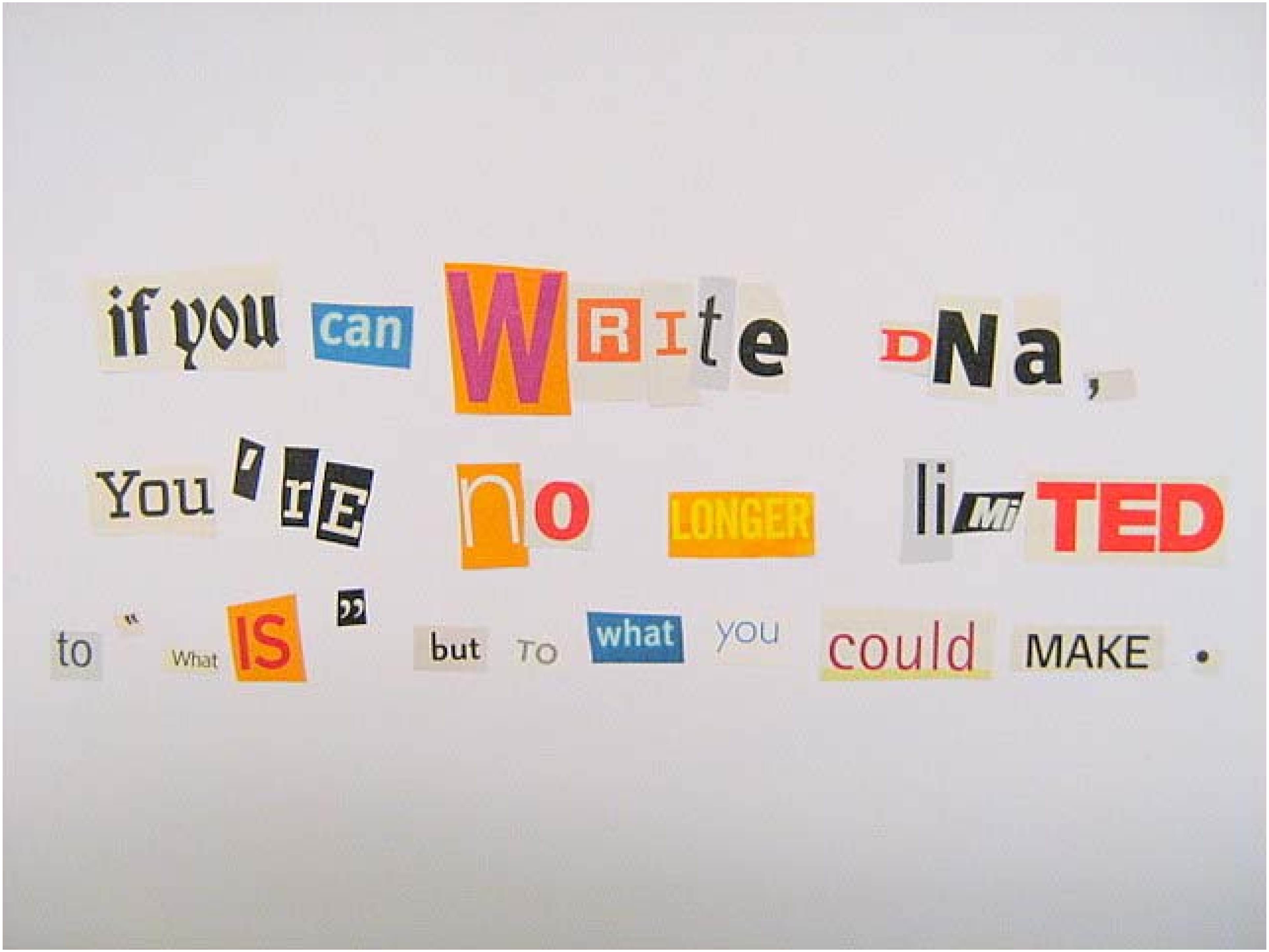

TIME
Prince Charles
Picks a
Bride
Shaping Life in the Lab
The Boom
In Genetic
Engineering
Genentech's
Herbert Boyer

REBASE®

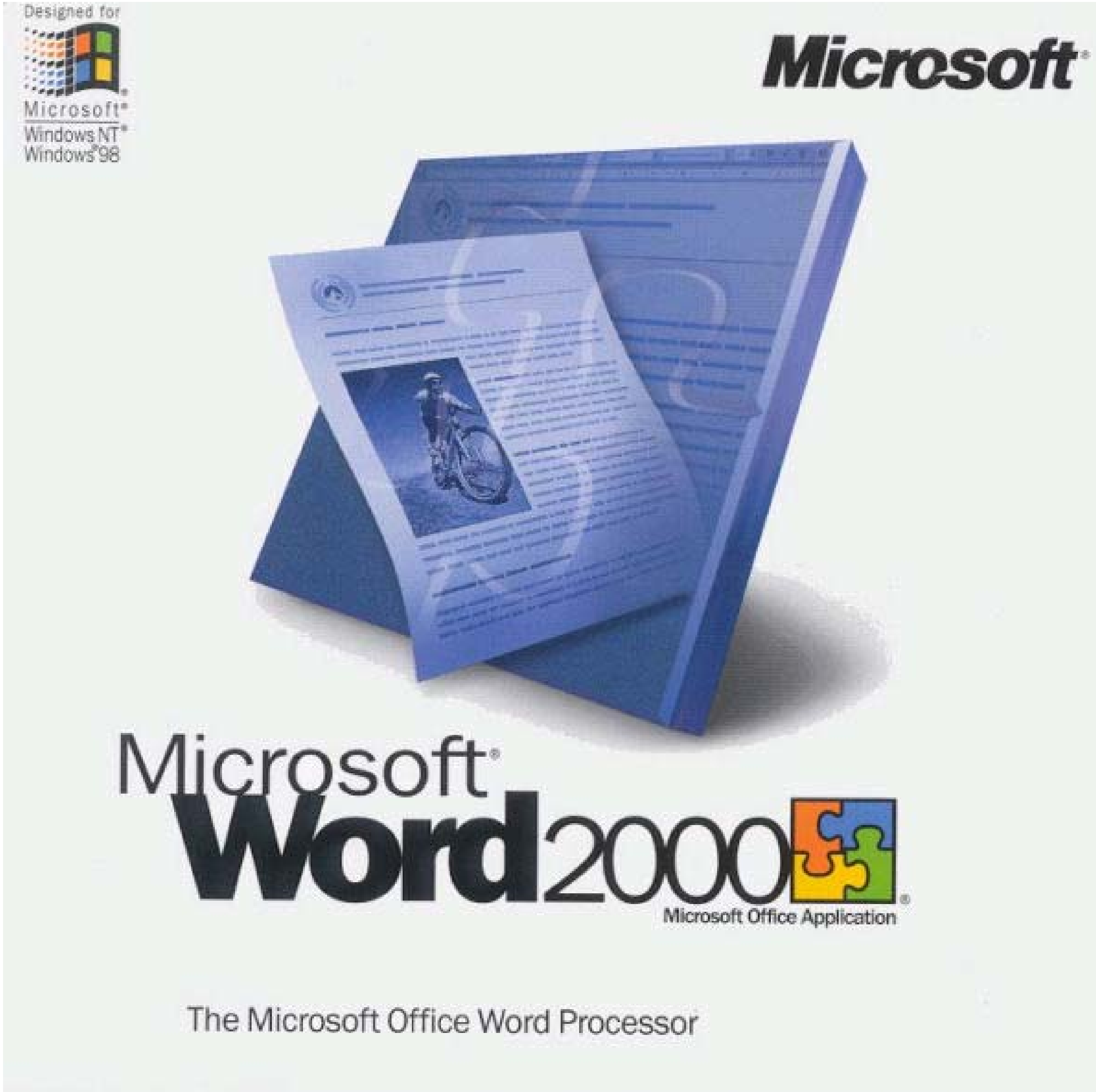
home page...
rebase.neb.com



Restriction Enzyme Action of EcoRI


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

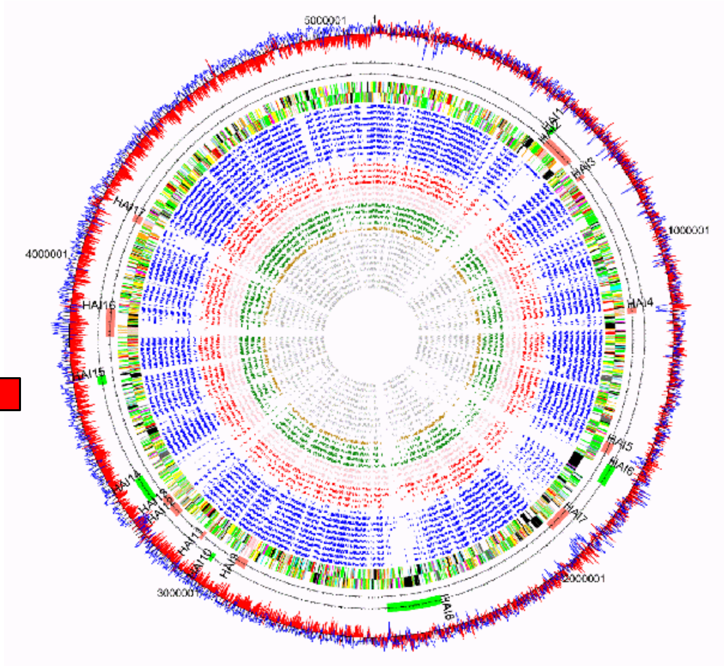
http://en.wikipedia.org/wiki/Image:Metal_movable_type.jpg


Designed for
Microsoft®
Windows NT®
Windows®98
Microsoft®
Microsoft®
Word2000
Microsoft Office Application
The Microsoft Office Word Processor

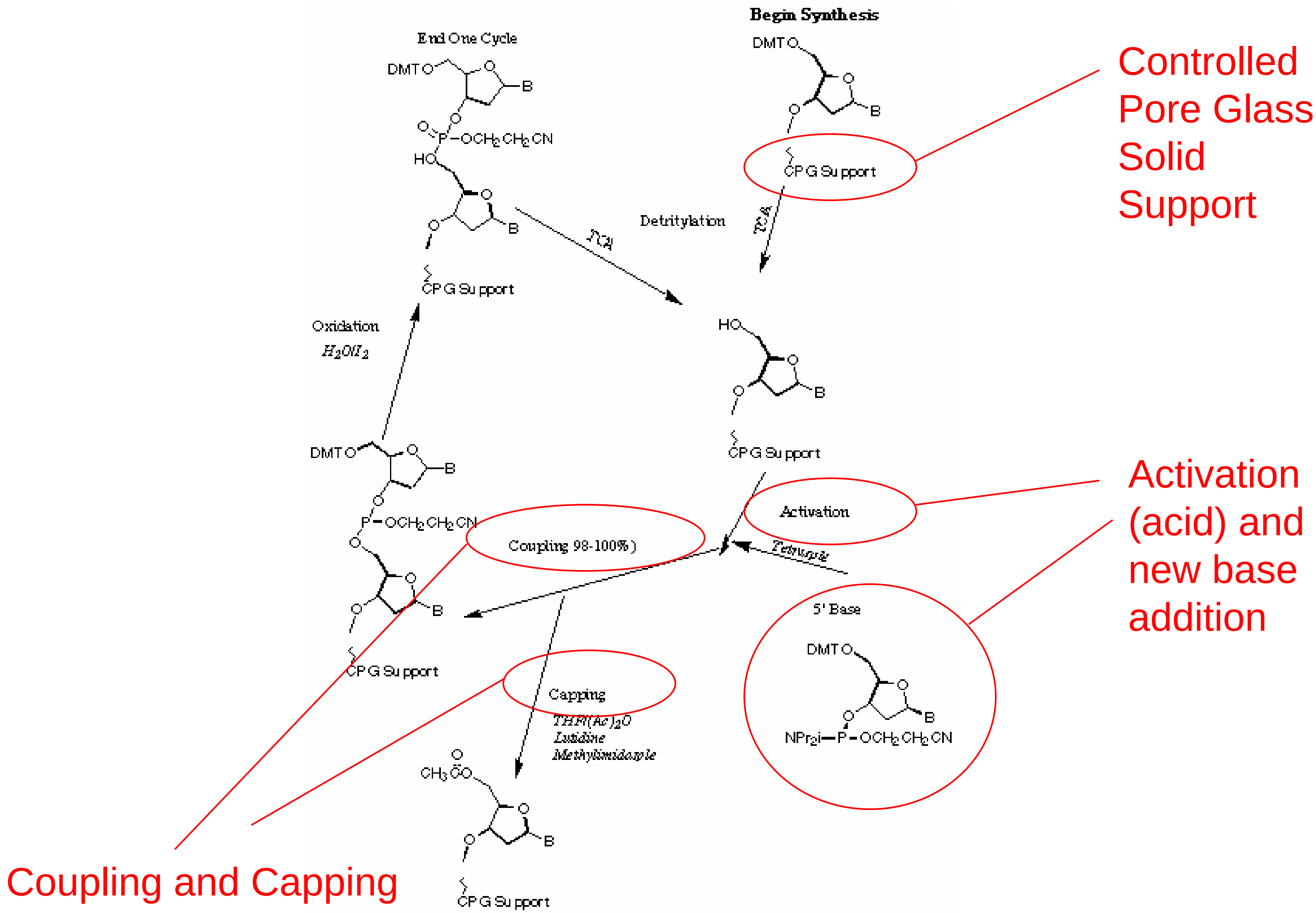
Physical DNA

sequencing

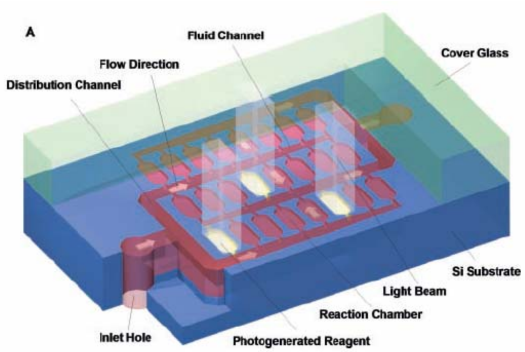
synthesis

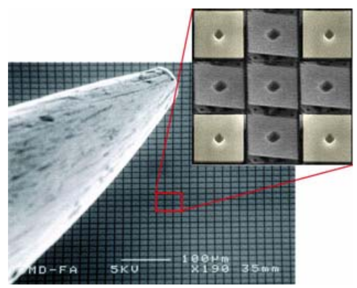


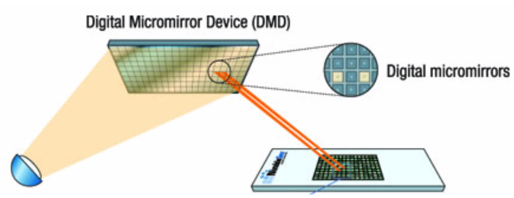
Digital DNA

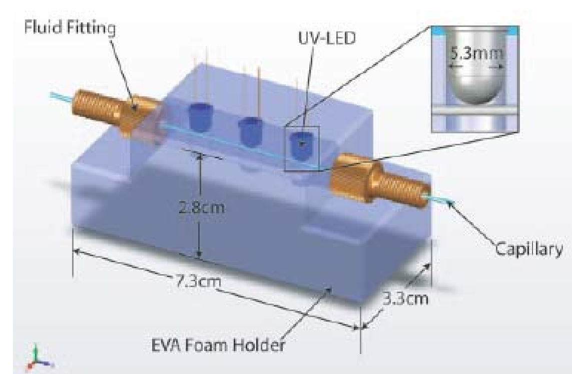

Begin Synthesis
End One Cycle
Detritylation
TCA
Oxidation
H_2O/I_2
Activation
Tetrazole
Coupling 98-100%)
Capping
$THF/(Ac)_2O$
Lutidine
Methylimidazole
5' Base
CPG Support
Controlled Pore Glass Solid Support
Activation (acid) and new base addition
Coupling and Capping


BECKMAN


A
Fluid Channel
Flow Direction
Cover Glass
Distribution Channel
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

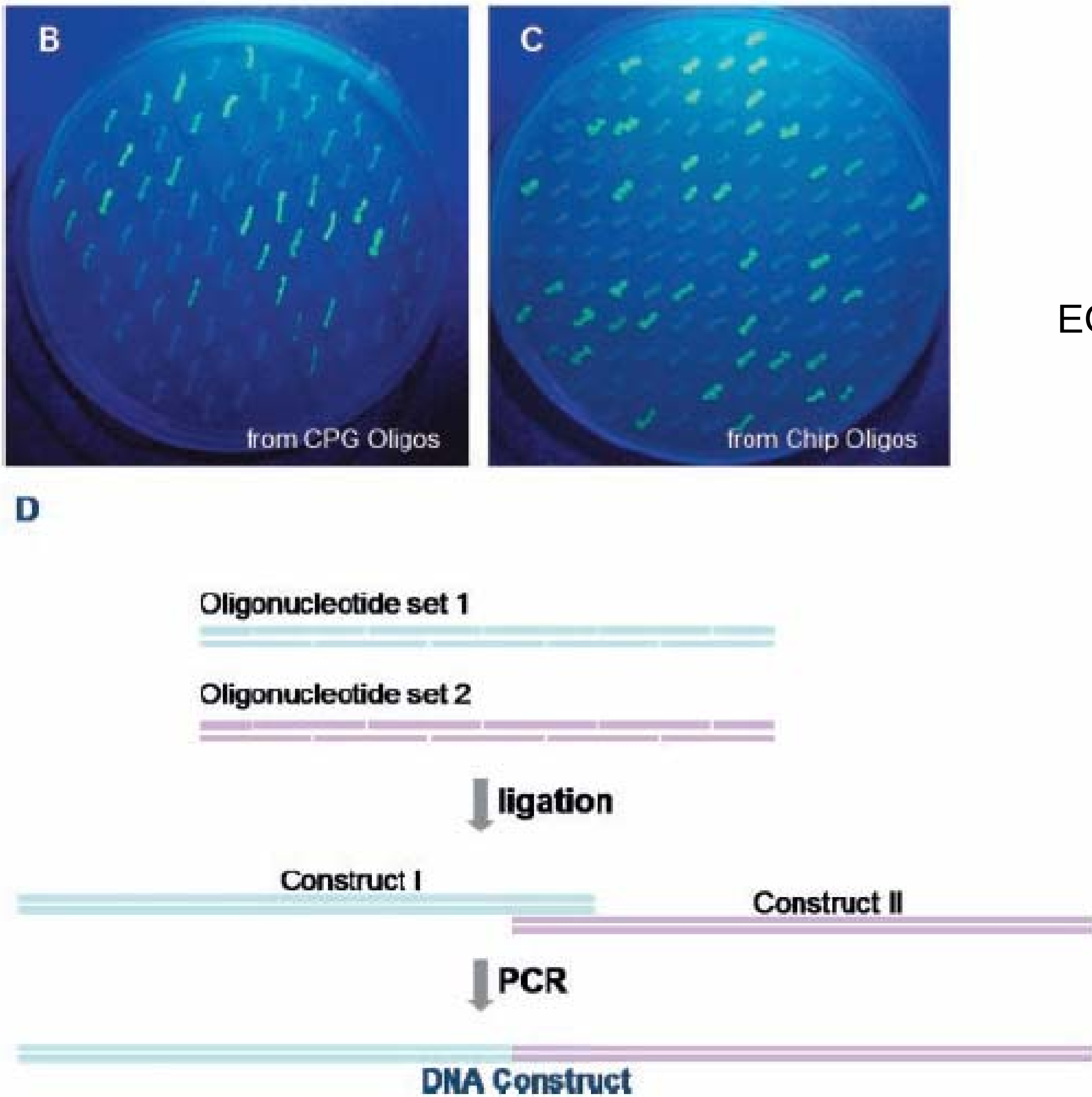
Milli GEN/Biosearch 8700 DNA Synthesizer

Seller of this item? Sign in for your status

1 of 6

Supersize

Starting bid:	**US $89.99** Place Bid >
End time:	**May-04-07 08:30:40 PDT** (1 day 7 hours)
Shipping costs:	Check item description and payment instructions or contact seller for details
Ships to:	United States
Item location:	Saint Louis, Missouri, United States
History:	0 bids
You can also:	Watch This Item
	Get alerts via Text message, IM or Cell phone
	Email to a friend



EGFP gene 714 bp

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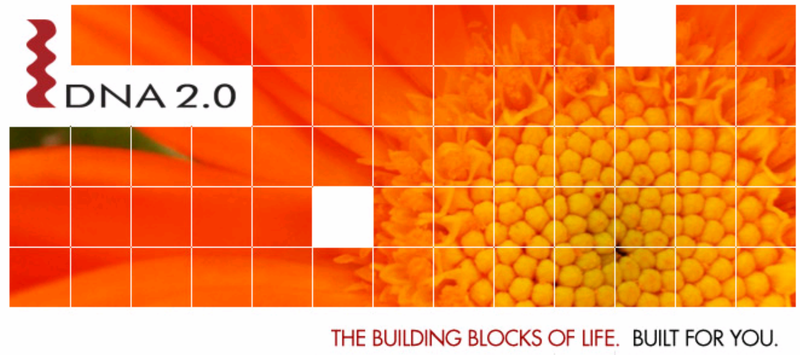
www.epochbiolabs.com

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

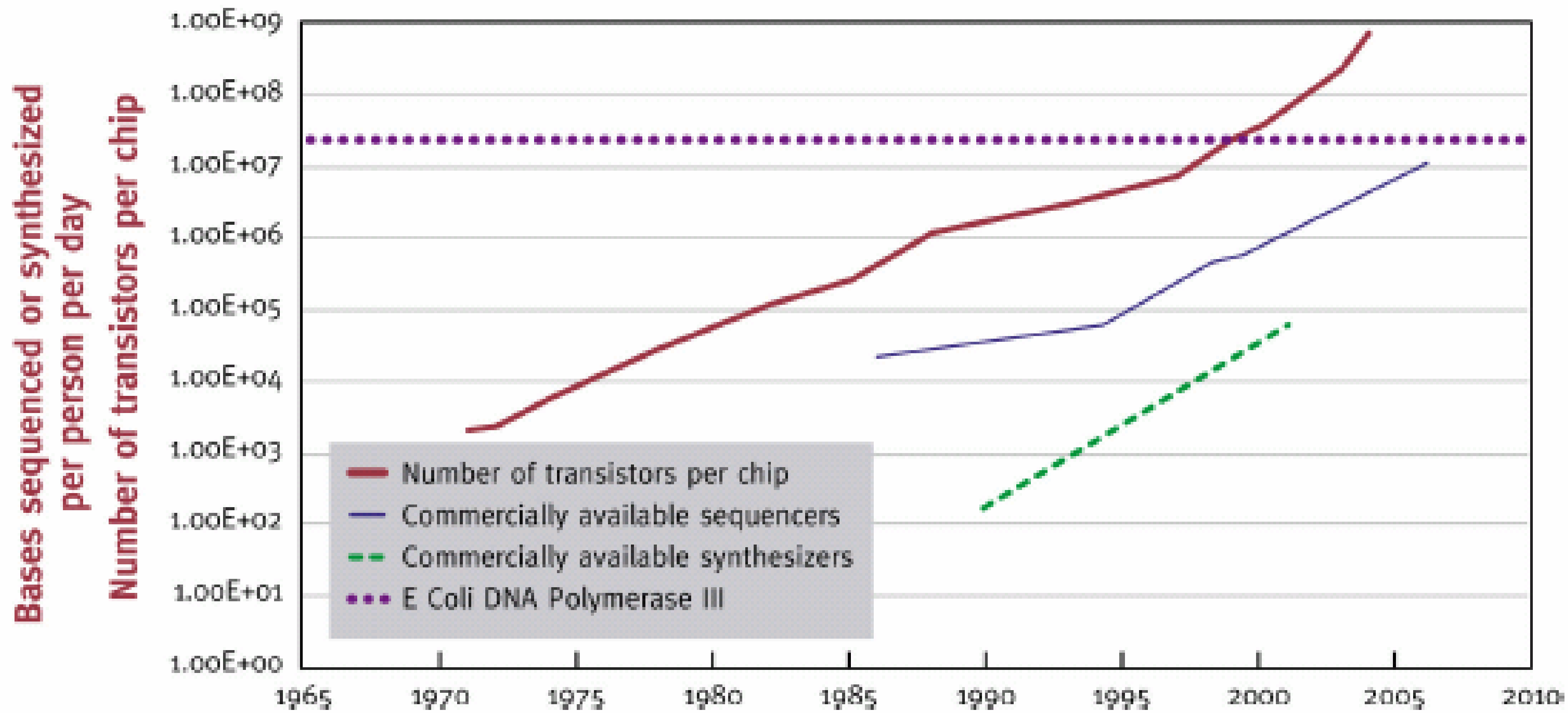
Gene Synthesis - $0.69/bp
All purpose **gene synthesis**.
Speed up R&D. Save money, time.
www.codondevices.com

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

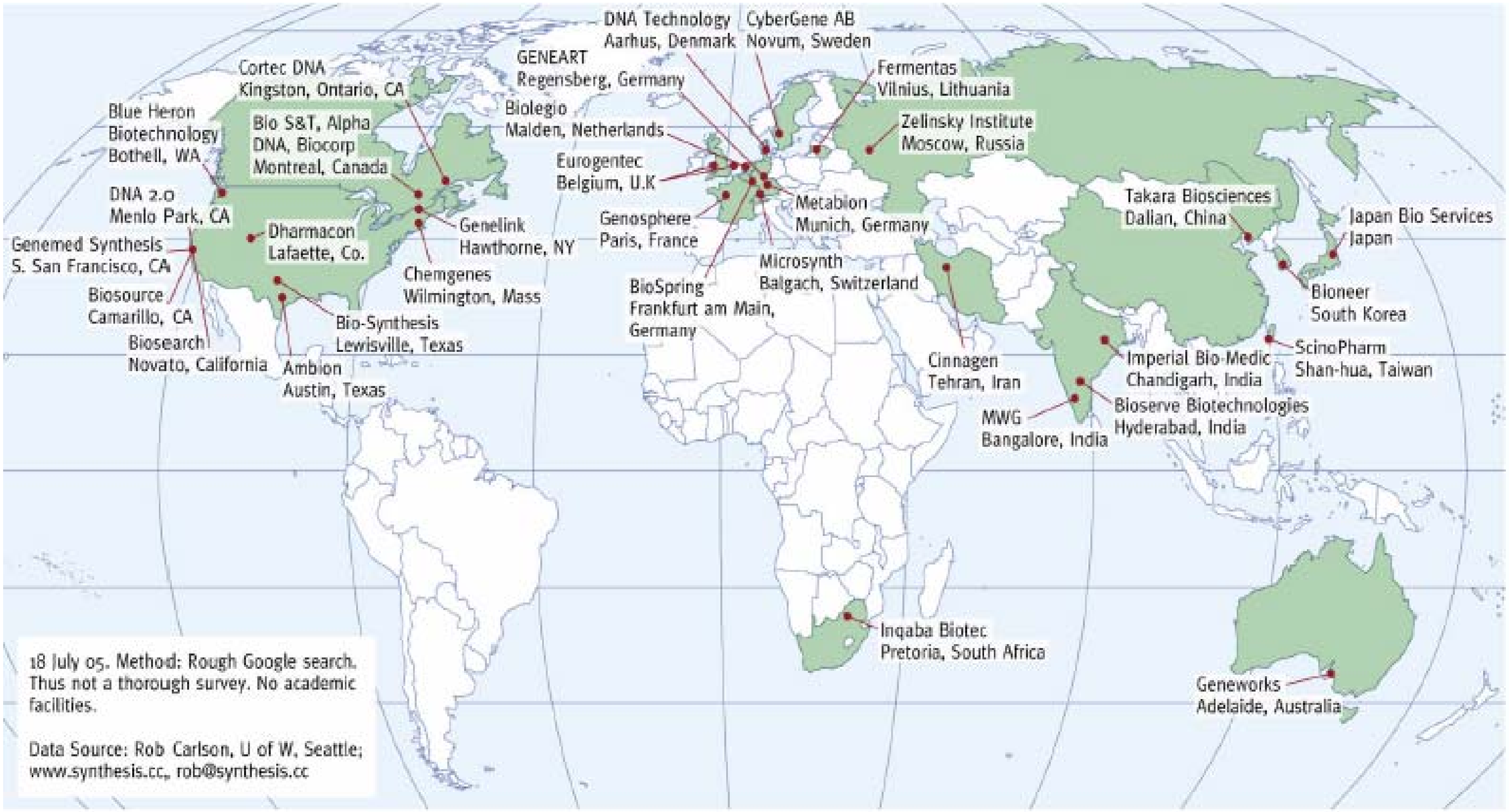
Gene Synthesis
OligoMix - Oligonucleotide Mixture
gene construction / **synthesis**
www.lcsciences.com



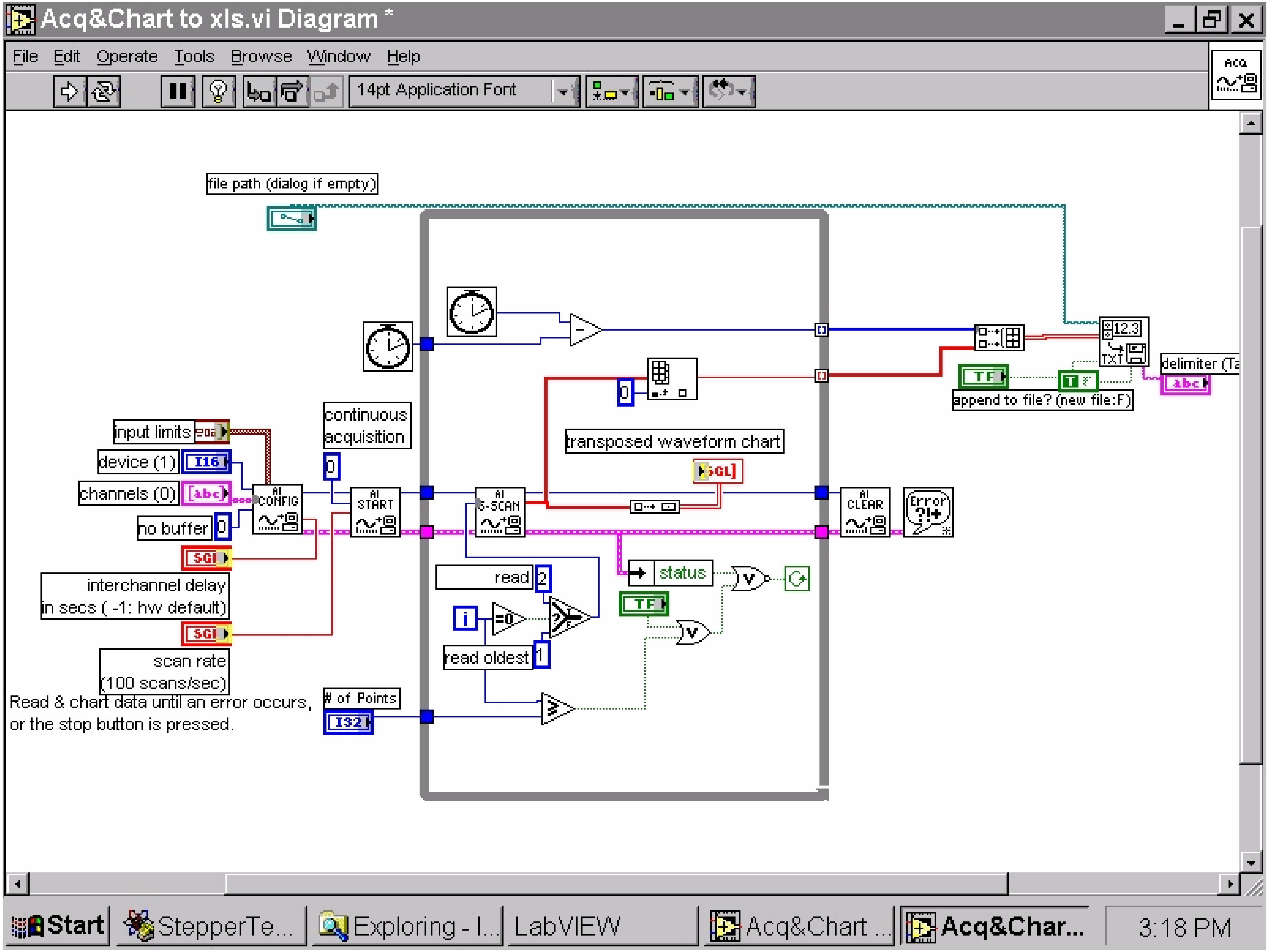
BLUEHERON®
BIOTECHNOLOGY



Source: R. Carlson, Bio-era.



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


Acq&Chart to xls.vi Diagram *
File Edit Operate Tools Browse Window Help
14pt Application Font
file path (dialog if empty)
continuous acquisition
input limits
device (1)
channels (0)
no buffer
interchannel delay in secs (-1: hw default)
scan rate (100 scans/sec)
Read & chart data until an error occurs, or the stop button is pressed.
# of Points
transposed waveform chart
read
read oldest
status
append to file? (new file:F)
delimiter (Ta
AI CONFIG
AI START
AI S-SCAN
AI CLEAR
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Exploring - I...
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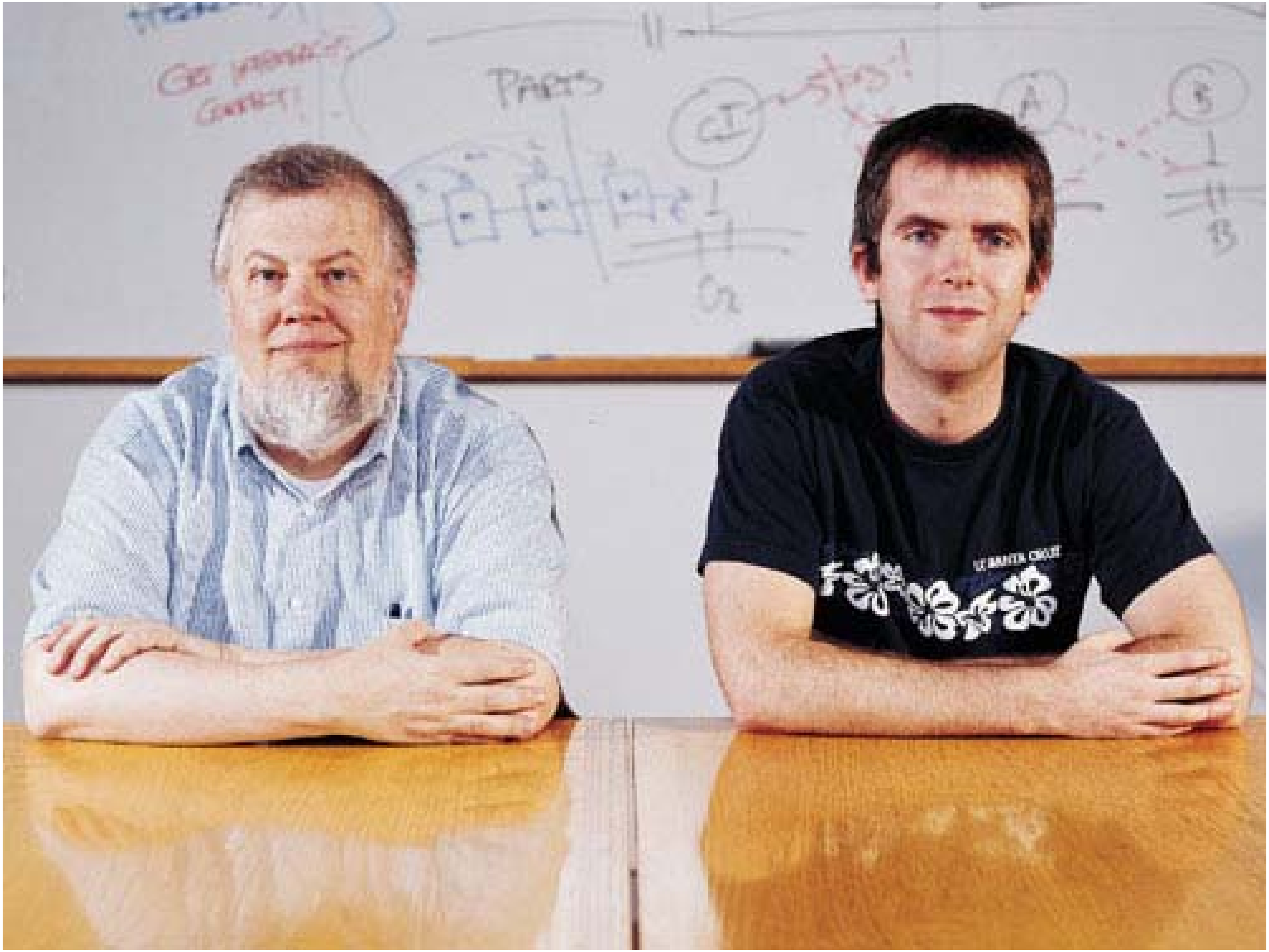
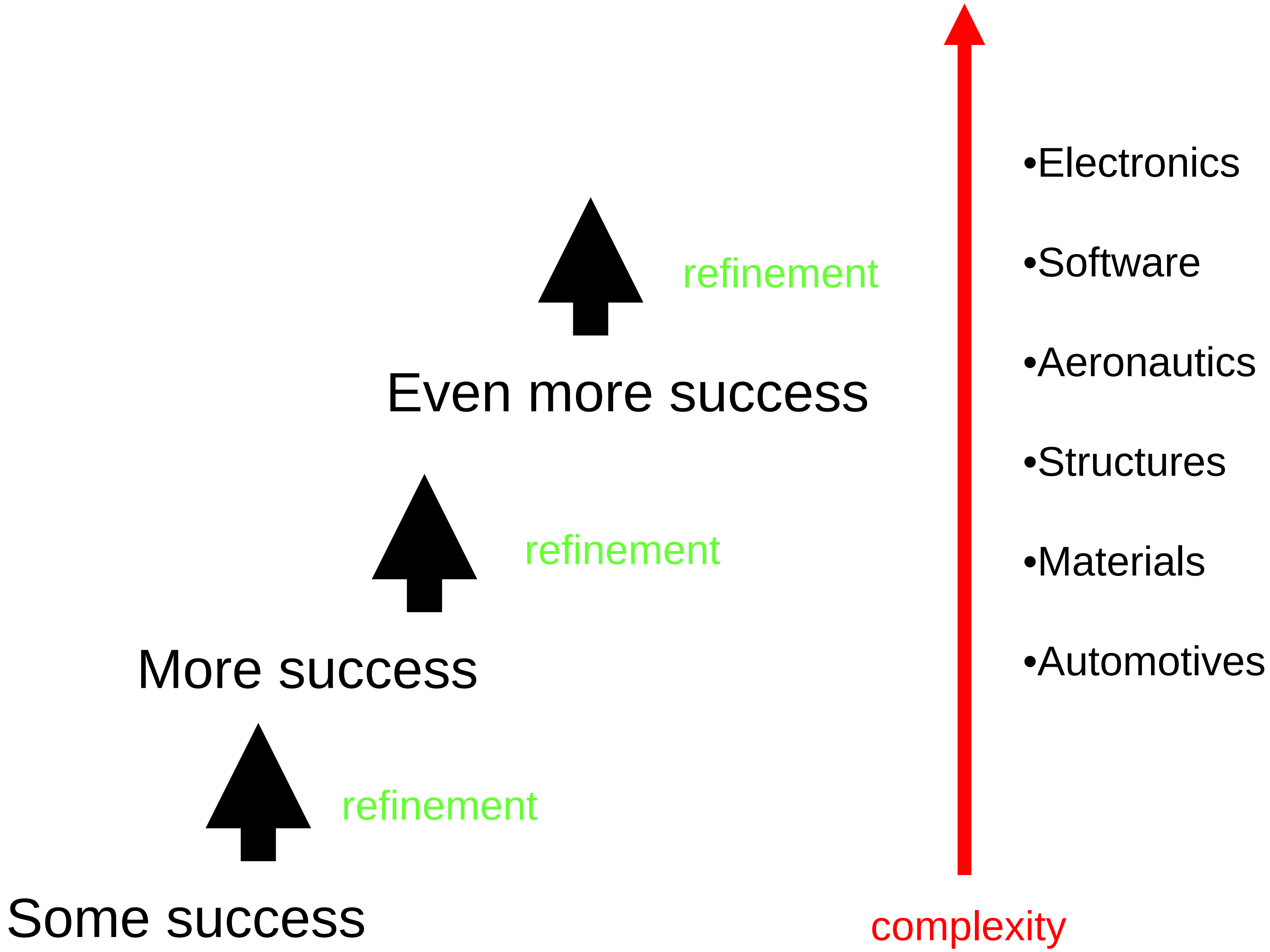


Engineering process…



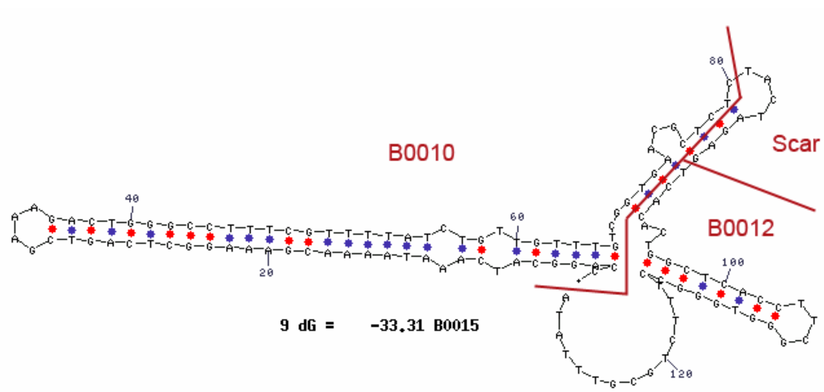
F1760

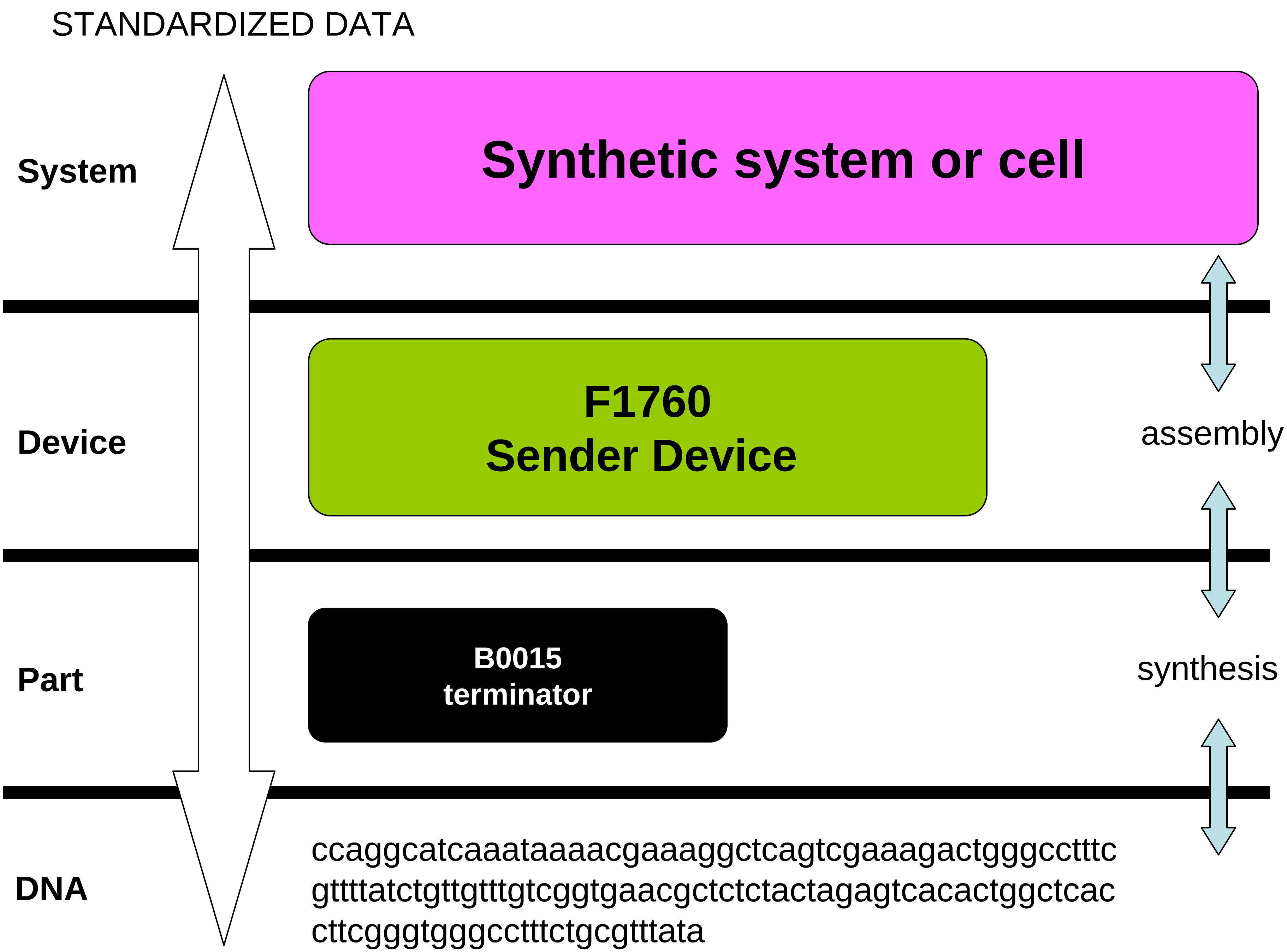
Sender Device

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

Create an account or log in

article

Transcriptional Regulators

jump to part

BBa_

navigation

- Main Page
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- Recent changes
- Recent part changes

resources

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- Add a Part
- Part Searches
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- Help

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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*

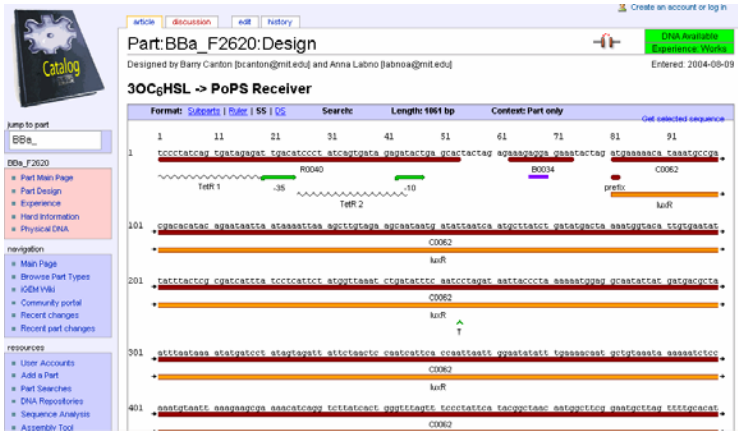
-?-		Name	Description	Direction	Control -?-	Output Low	Output High	Length
A		BBa_I12007	Modified lambda Prm promoter (OR-3 obliterated)	Forward	cI			82
A		BBa_R0062	Promoter (luxR & HSL regulated -- lux pR)	Forward	luxR, HSL			55
A		BBa_R0079	Promoter (LasR & PAI regulated)	Forward	PAI			157
A		BBa_R0080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

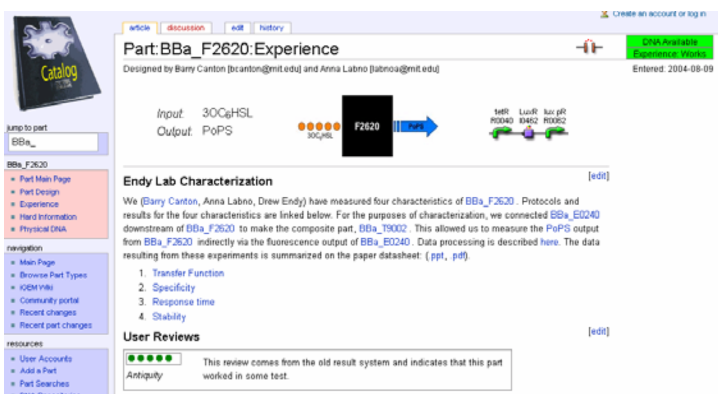
Available other regulators

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

http://parts.mit.edu





BBa_F2620

$3OC_6HSL$ → PoPS Receiver

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

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

Last Update: 15 January 2007

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 aTc can be used to produce a Boolean AND function.

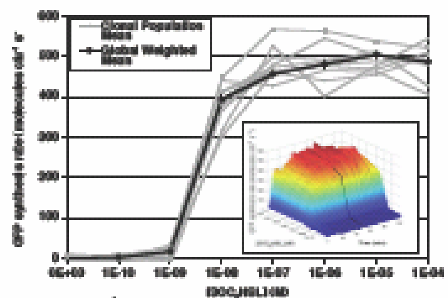
Characteristics

Input Swing:	1E-9 to 1E-6 M $3OC_6HSL$, exogenous
Output Swing:	0±1 to 503±1 GFP molecules cfu^{-1} s^{-1}
Switch Point:	7±1 nM $3OC_6HSL$, exogenous
LH Response:	9 min ($t_{50\%}$), 27 min ($t_{90\%}$)

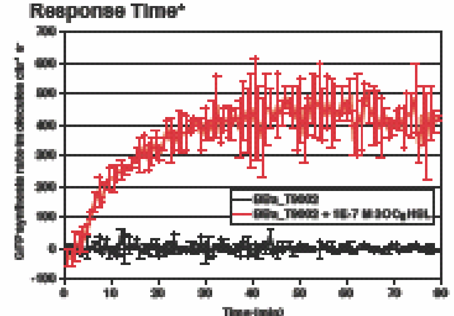
Key Parts

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

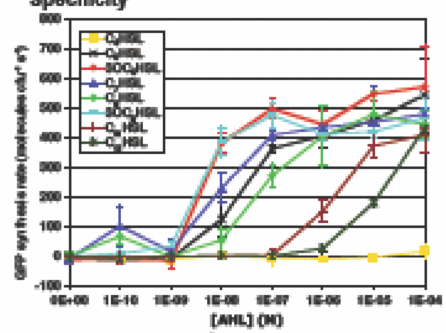
Transfer Function*



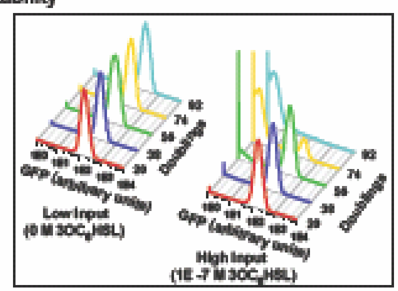
Response Time*



Specificity*



Stability**



Demand (low/high input)

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

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 $3OC_6HSL$

Stability (low/high input)

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

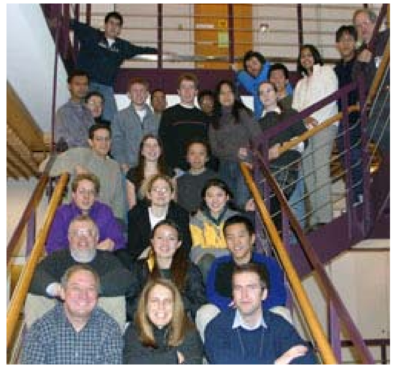
Conditions (abridged)

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

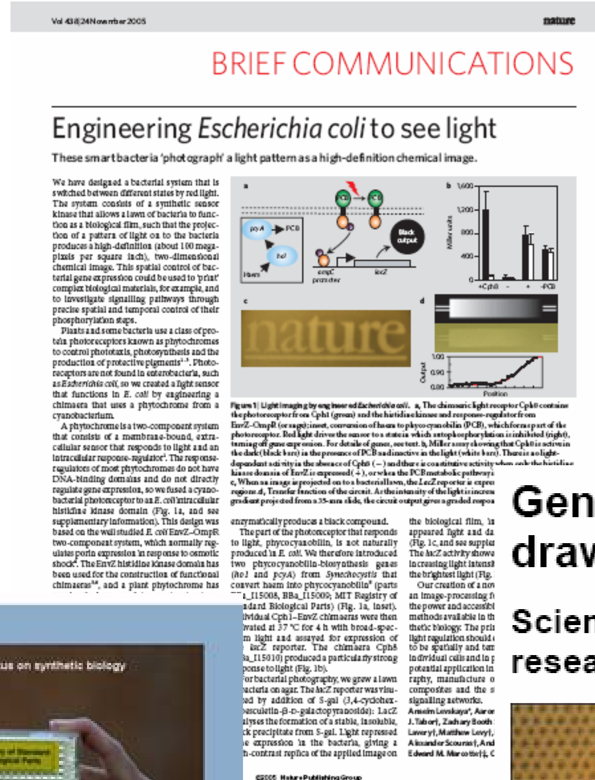
Signaling Devices

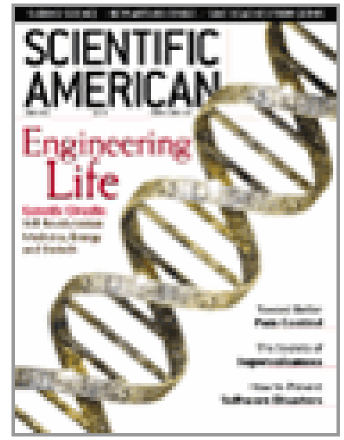
Shares:

- DNA parts
- DNA code
- Protocols
- Experience
- Publications
- One big rule: share back!



2006 Jamboree – 400 gengineers





COVER STORY

By Carl Zimmer

Scientist of the Year

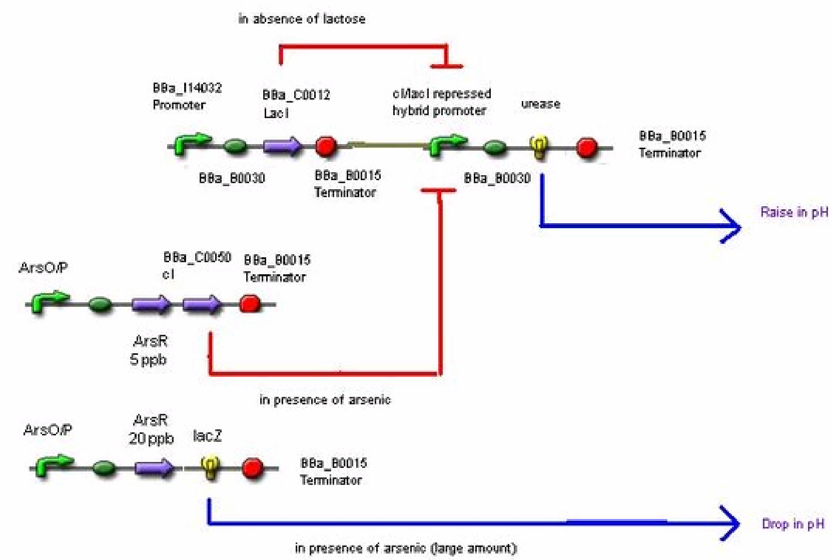
Jay Keasling is developing ways to program DNA as easily as people program computers.

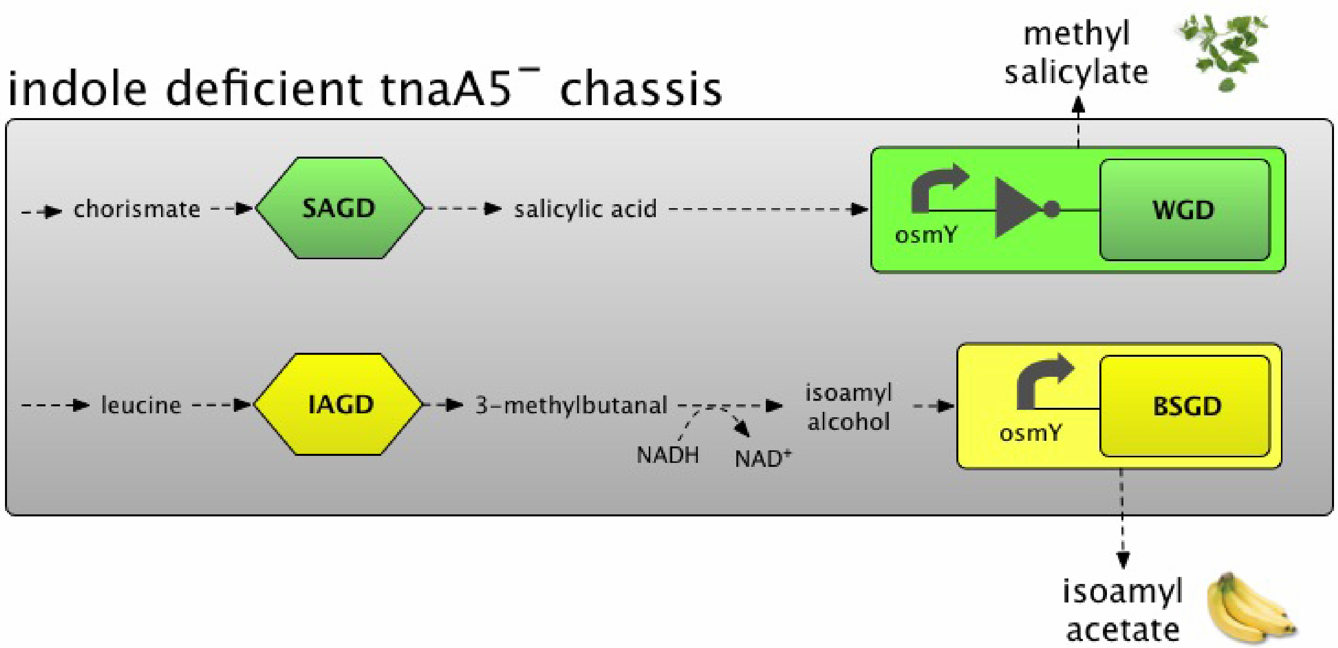
Genetic 'Jamboree' draws innovators

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)


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 Wiki

International Genetically Engineered Machine Competition

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teams jamboree participate help about registry

The University of Ljubljana

They became the reigning champion of iGEM last year after winning the Grand Prize and returning to Slovenia with the coveted BioBrick trophy. This year they are building synthetic defender cells for the immune system.

Jamboree

sat & sun, nov 3-4

The Jamboree is the culmination of iGEM. Lots of information is on the Jamboree Page, or jump right to:

- schedule
- Jamboree Registration
- hotels
- compete
- dna submission

iGEM?

Hundreds of undergraduates all over the world spend their summer making Synthetic Biology a reality by participating in the annual International Genetically Engineered Machine competition.

Learn More

calendar

Jamboree roster + fees due	fri 12 oct 12
iGEM wiki frozen + parts postmarked	fri 26 Oct 07
Jamboree!	sat-sun 3-4 nov 07
Registry + BioBrick foundation workshops	sun-tue 4-6 nov 07

iGEM Press

Harvard
Brown
Boston
McGill
Waterloo
Toronto
Edmonton
Calgary
Lethbridge
Utah
Missouri
Davidson/Missouri
Bay Area RSI
Berkeley LBL
Berkeley UC
UCSF
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Mississippi
Rice
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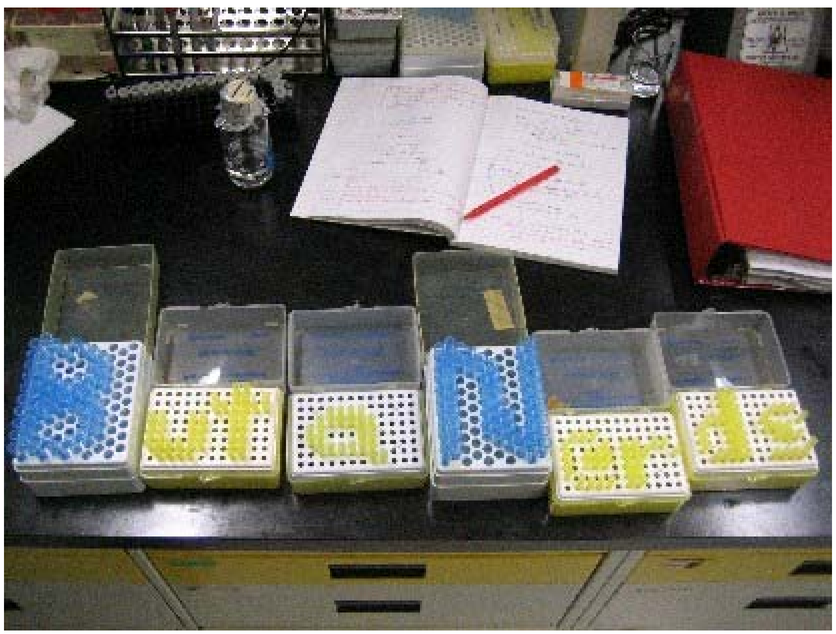
Mexico
Minnesota
Colombia
Wisconsin
Michigan
Duke
Purdue
Virginia Tech
Virginia
Princeton
Penn State
CSHL
MIT
Imperial
Cambridge
Dundee
Edinburgh
Glasgow
Paris
St. Petersburg
ETHZ
Freiburg
Ljubljana
Valencia
Bologna
Naples
Turkey
Bangalore
Peking
UST China
Tsinghua
Tianjin
Tokyo
Chiba
Taipei
Melbourne


The University of Alberta's
Butanerds
"Save the Ethanol for Drinkin' "
Butanol


ButaNerds

UNIVERSITY BUSINESS

Alberta Students Finance Electronic Application Assistance

MEDIA

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EVENTS

Oct 23, 2007

Flu Clinics for Students in Health Faculties

Landscape and Culture: The Social Meaning of Place

Who Protects the Protectors? Health, War & Society Film Series

U of A team building a better bacterium

By **Ileiren Poon**, ExpressNews Staff

Members of the U of A Buta-nerds team are collecting data for a Nov. competition at MIT.

Print story | Email story

U of A team prepares for MIT competition in November:

October 22, 2007 - Edmonton - A group of University of Alberta students have spent the summer working on building a new kind of bacteria - one that might hold some answers to the planet's diminishing supply of fossil fuels.

The team members - who call themselves the Buta-nerds - have been working on a way to create an organism that will produce butanol fuel for an annual competition hosted by

FEATURES

Refashioned Royal Society to meet at U of A

Video: Report to the Community 2007

OPINION

Guest Column: Once Putin leaves office, he won't return

Student View: Travel experience will influence career in criminology

ATHLETICS

Dylan Stanley is the Canada West Player of the Week

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President Samarasekera

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.

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.

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.


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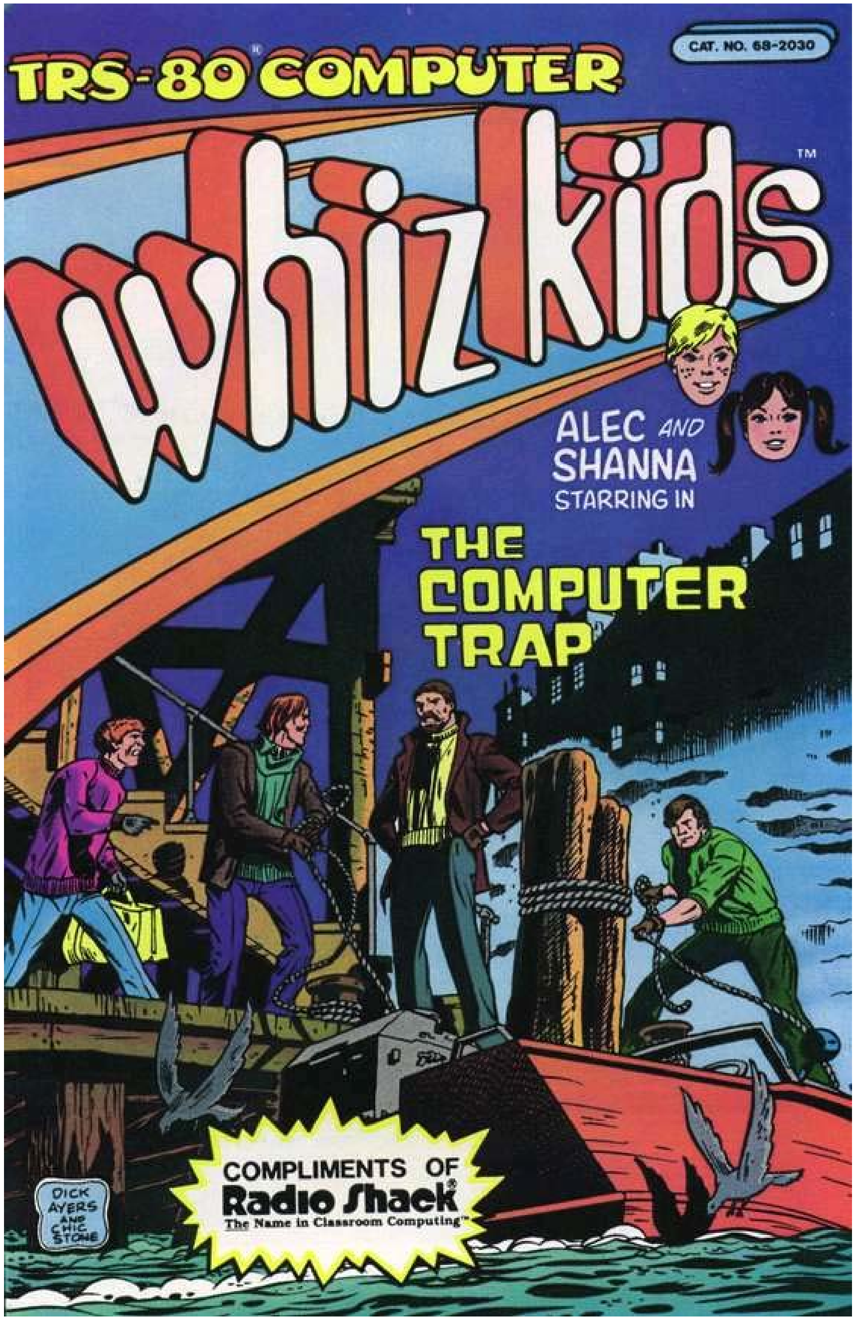
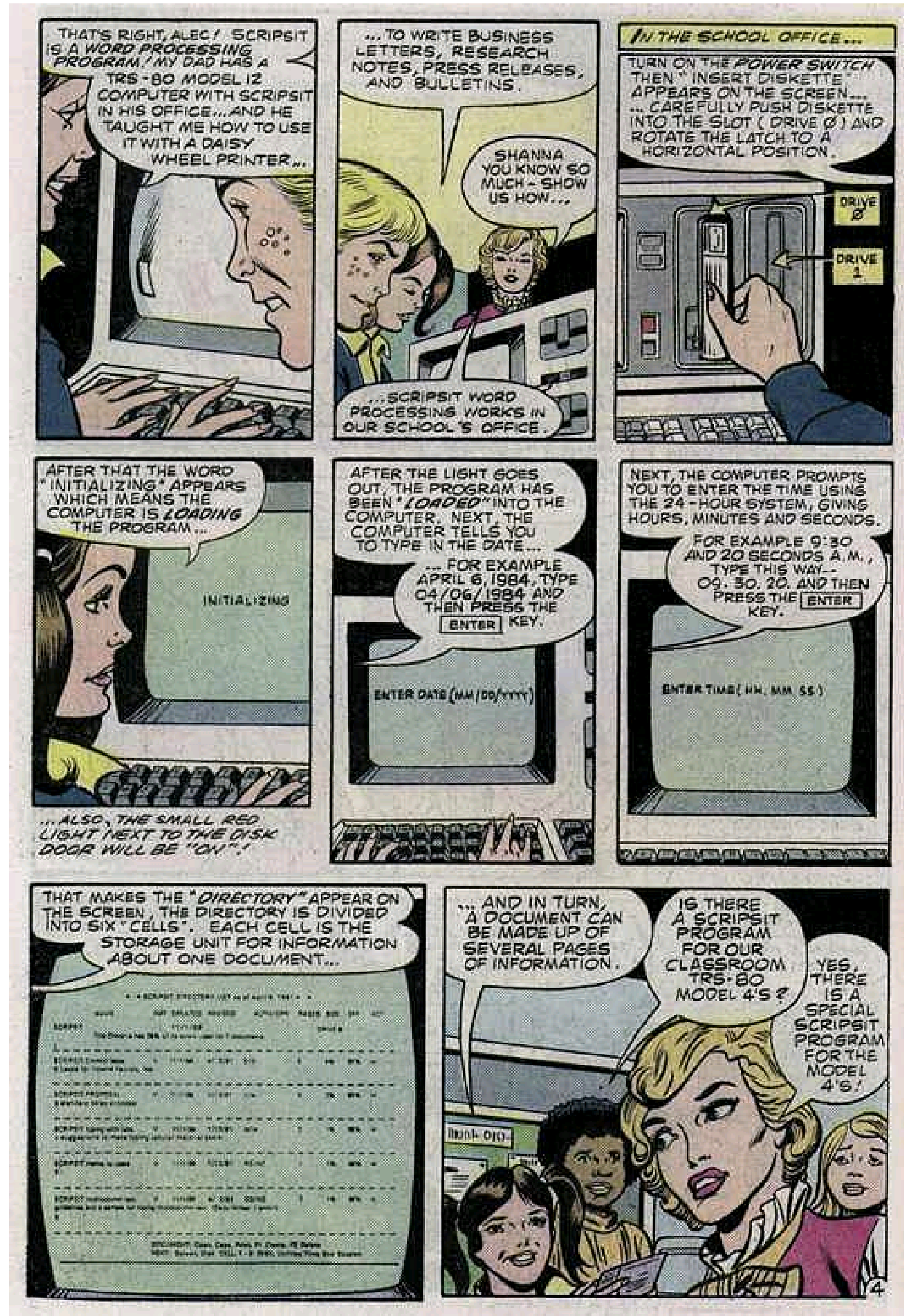
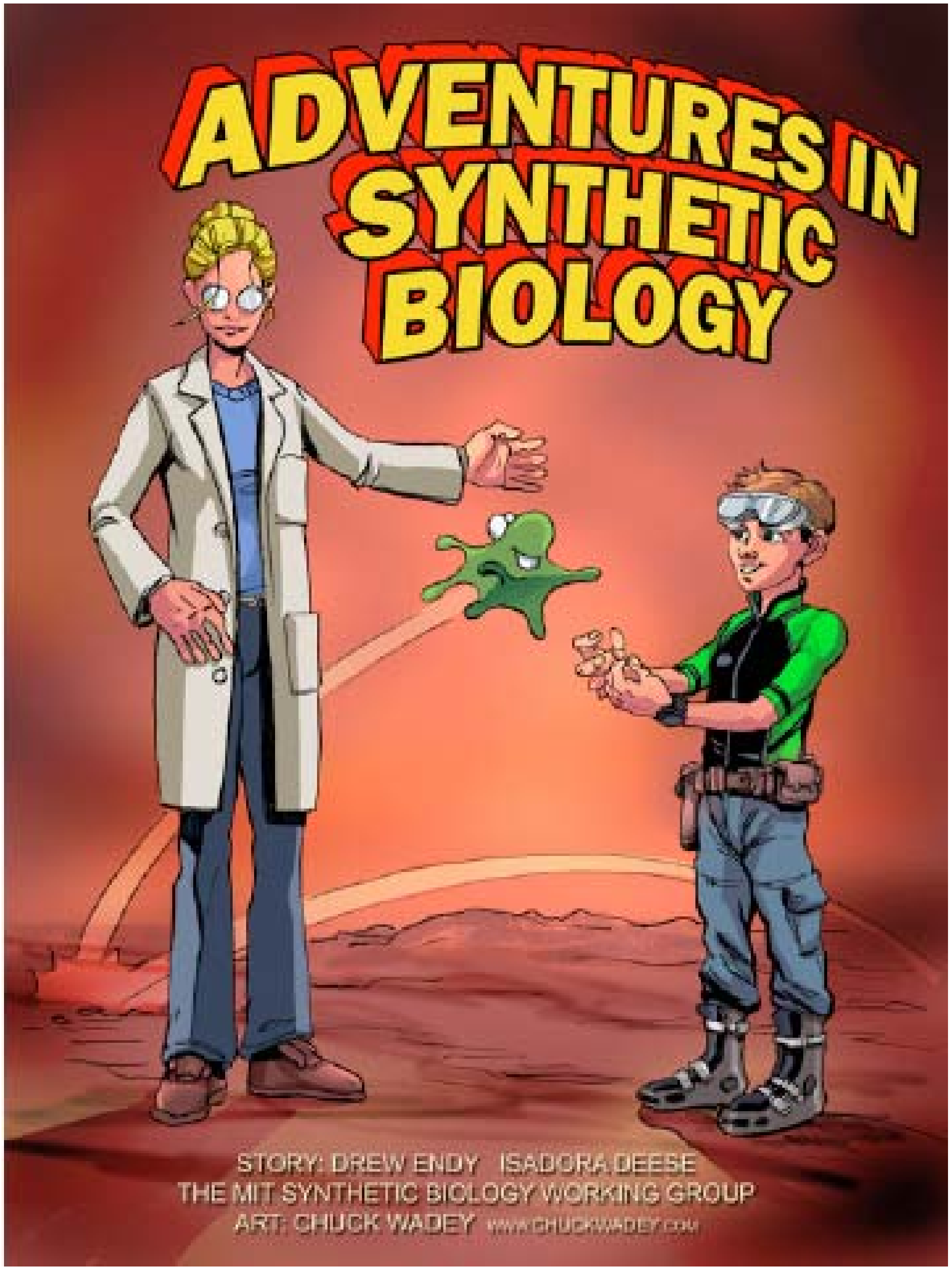
$1.50
TIME
-.3%
INFLATION VANISHES!
At Least for A Month
COMPUTER GENERATION
A New Breed of Whiz Kids

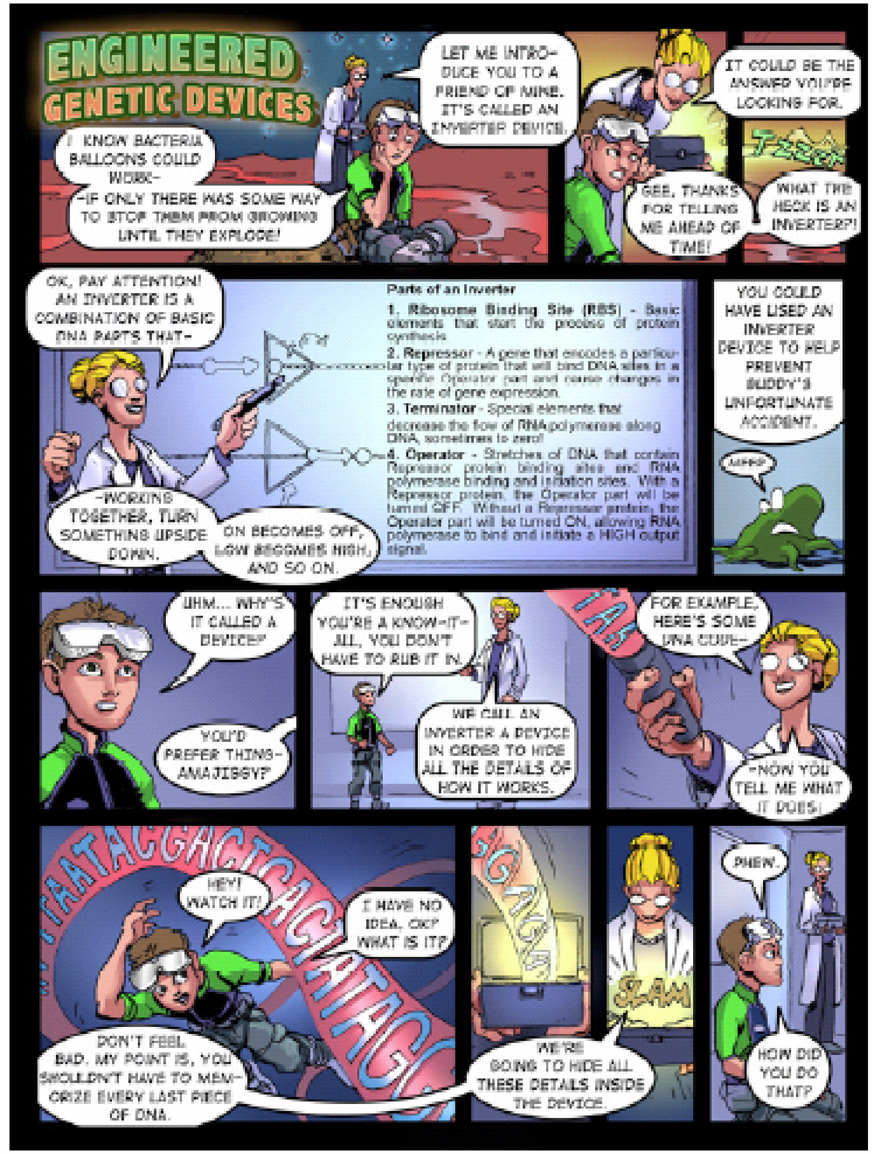


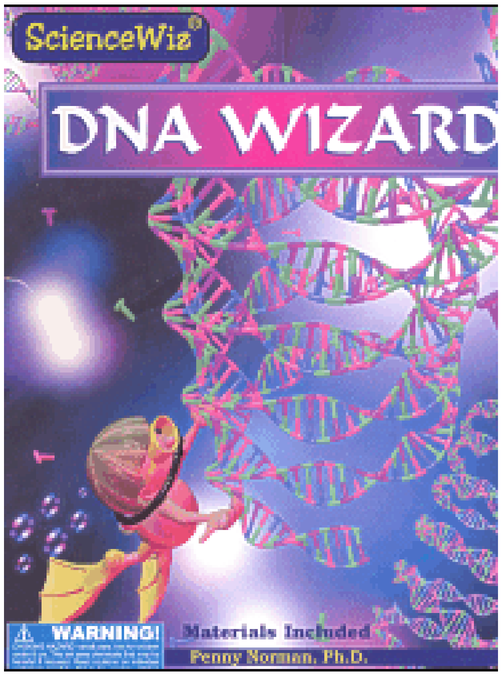
TRS-80® COMPUTER
CAT. NO. 68-2030
whiz kids™
ALEC AND SHANNA STARRING IN
THE COMPUTER TRAP
COMPLIMENTS OF Radio Shack® The Name in Classroom Computing™
DICK AYERS AND CHIC STONE

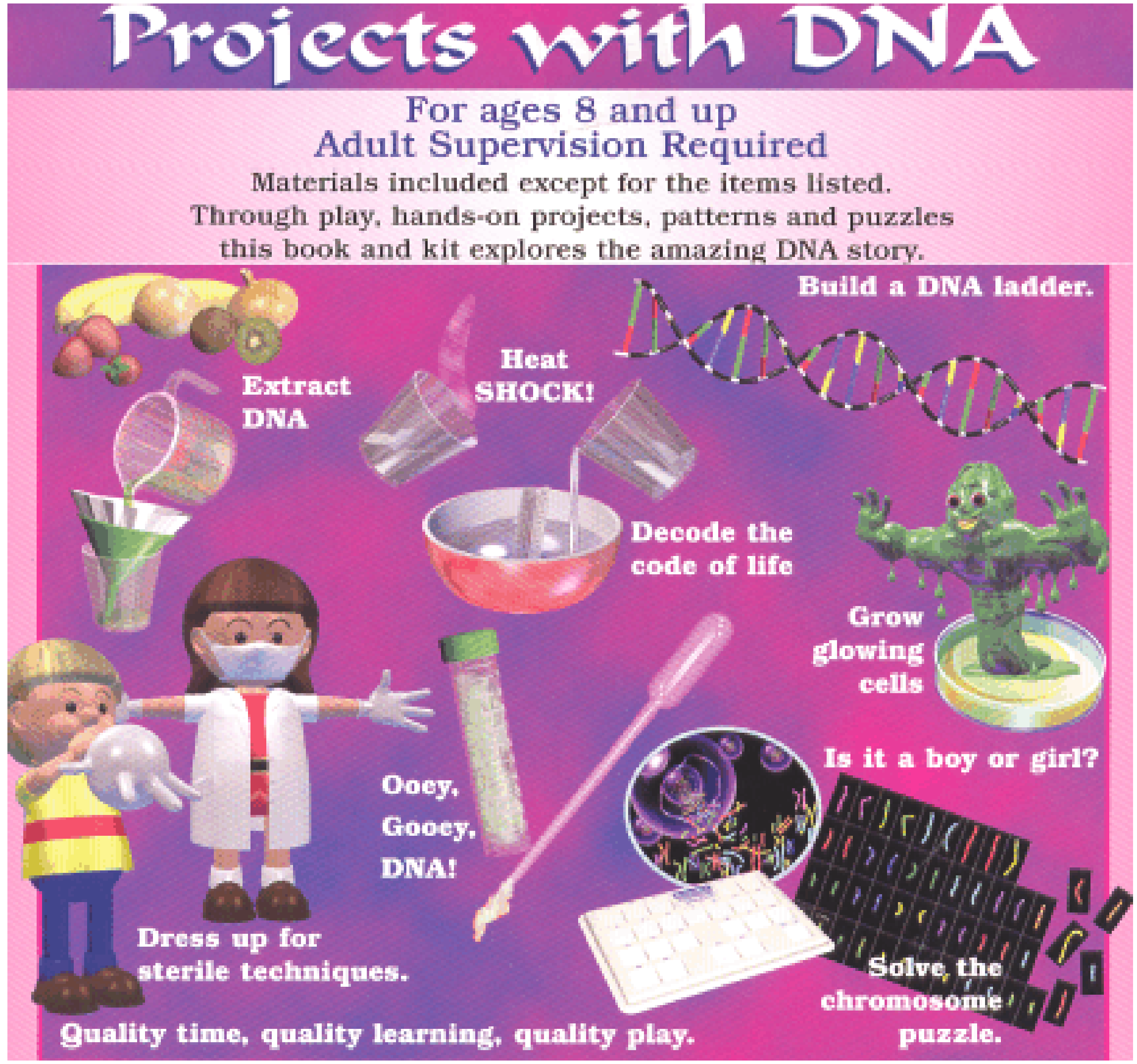


THAT'S RIGHT, ALEC! SCRIPSIT IS A WORD PROCESSING PROGRAM! MY DAD HAS A TRS-80 MODEL 12 COMPUTER WITH SCRIPSIT IN HIS OFFICE...AND HE TAUGHT ME HOW TO USE IT WITH A DAISY WHEEL PRINTER...
...TO WRITE BUSINESS LETTERS, RESEARCH NOTES, PRESS RELEASES, AND BULLETINS.
SHANNA YOU KNOW SO MUCH – SHOW US HOW...
...SCRIPSIT WORD PROCESSING WORKS IN OUR SCHOOL'S OFFICE.
IN THE SCHOOL OFFICE...
TURN ON THE POWER SWITCH THEN "INSERT DISKETTE" APPEARS ON THE SCREEN... ...CAREFULLY PUSH DISKETTE INTO THE SLOT (DRIVE Ø) AND ROTATE THE LATCH TO A HORIZONTAL POSITION.
DRIVE Ø
DRIVE 1
AFTER THAT THE WORD "INITIALIZING" APPEARS WHICH MEANS THE COMPUTER IS LOADING THE PROGRAM...
INITIALIZING
...ALSO, THE SMALL RED LIGHT NEXT TO THE DISK DOOR WILL BE "ON"!
AFTER THE LIGHT GOES OUT, THE PROGRAM HAS BEEN "LOADED" INTO THE COMPUTER. NEXT, THE COMPUTER TELLS YOU TO TYPE IN THE DATE...
...FOR EXAMPLE APRIL 6, 1984, TYPE 04/06/1984 AND THEN PRESS THE ENTER KEY.
ENTER DATE (MM/DD/YYYY)
NEXT, THE COMPUTER PROMPTS YOU TO ENTER THE TIME USING THE 24-HOUR SYSTEM, GIVING HOURS, MINUTES AND SECONDS.
FOR EXAMPLE 9:30 AND 20 SECONDS A.M., TYPE THIS WAY-- 09. 30. 20. AND THEN PRESS THE ENTER KEY.
THAT MAKES THE "DIRECTORY" APPEAR ON THE SCREEN, THE DIRECTORY IS DIVIDED INTO SIX "CELLS". EACH CELL IS THE STORAGE UNIT FOR INFORMATION ABOUT ONE DOCUMENT...
...AND IN TURN, A DOCUMENT CAN BE MADE UP OF SEVERAL PAGES OF INFORMATION.
IS THERE A SCRIPSIT PROGRAM FOR OUR CLASSROOM TRS-80 MODEL 4'S?
YES, THERE IS A SPECIAL SCRIPSIT PROGRAM FOR THE MODEL 4'S!
4


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

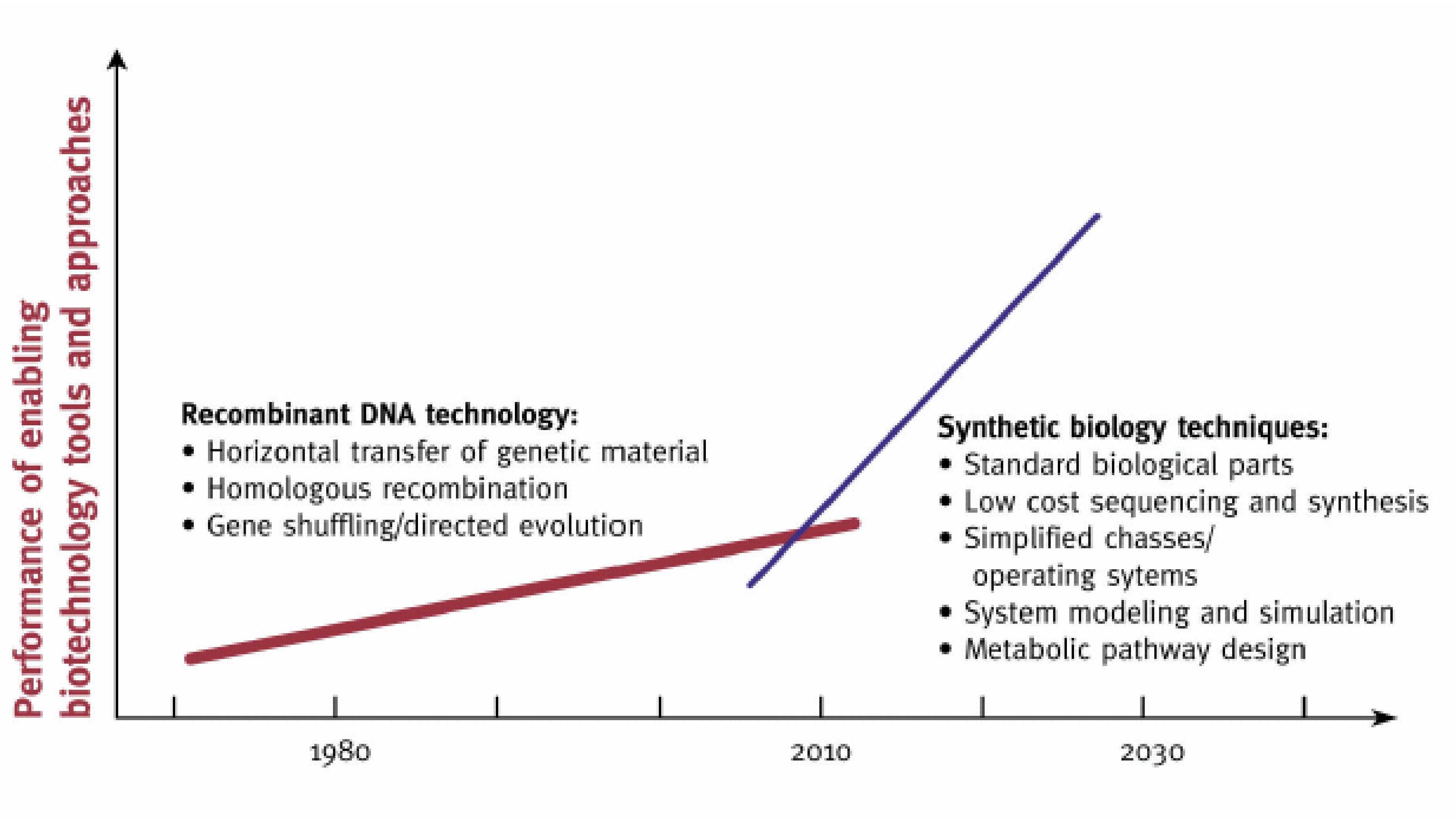

ENGINEERED GENETIC DEVICES
I KNOW BACTERIA BALLOONS COULD WORK–
–IF ONLY THERE WAS SOME WAY TO STOP THEM FROM GROWING UNTIL THEY EXPLODE!
LET ME INTRO-DUCE YOU TO A FRIEND OF MINE. IT'S CALLED AN INVERTER DEVICE.
IT COULD BE THE ANSWER YOU'RE LOOKING FOR.
GEE, THANKS FOR TELLING ME AHEAD OF TIME!
WHAT THE HECK IS AN INVERTER?!
OK, PAY ATTENTION! AN INVERTER IS A COMBINATION OF BASIC DNA PARTS THAT–
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.
–WORKING TOGETHER, TURN SOMETHING UPSIDE DOWN.
ON BECOMES OFF, LOW BECOMES HIGH, AND SO ON.
YOU COULD HAVE USED AN INVERTER DEVICE TO HELP PREVENT BUDDY'S UNFORTUNATE ACCIDENT.
UHM... WHY'S IT CALLED A DEVICE?
YOU'D PREFER THING-AMAJIGGY?
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 MEM-ORIZE 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/

Looking forward



Source: Bio era

Driving Forces

- Rapid advance of DNA sequencing, synthesis, and other enabling technologies
- Global growth of biotech R&D, knowledge, and applications
- Geopolitics; new security concerns
- Energy prices and climate change
- Urbanization and industrialization in developing economies

Major Uncertainties

- How quickly will biological engineering advance?
- Will governments attempt to restrict access to advanced biotech tools?
- How will public attitudes toward biological engineering evolve?
- Will the assertion of intellectual property rights slow innovation in synthetic biology?
- Will terrorists or governments use genome engineering techniques to create biological weapons?

Predetermined Elements

- Increasing environmental stress on global ecosystems
- Growing infectious disease threats to human and animal populations
- Human curiosity & technical innovation
- Growing healthcare needs of aging populations

Prime Movers

- U.S. government: DOE, NIH, NSABB, USPTO
- Biological engineering researchers
- "Open source" biology community
- Bioterrorists
- Energy, chemical, and pharmaceutical industries

Source: Bio era

Source: Bio era

Photo Credit: By Joby Warrick -- The Washington Post Photo

Sciencexpress Research Article

Genome Transplantation in Bacteria: Changing One Species to Another

Carole Lartigue, John I. Glass,* Nina Alperovich, Rembert Pieper, Prashanth P. Parmar, Clyde A. Hutchison III, Hamilton O. Smith, J. Craig Venter

The J. Craig Venter Institute, Rockville, MD 20850, USA.

science theguardian

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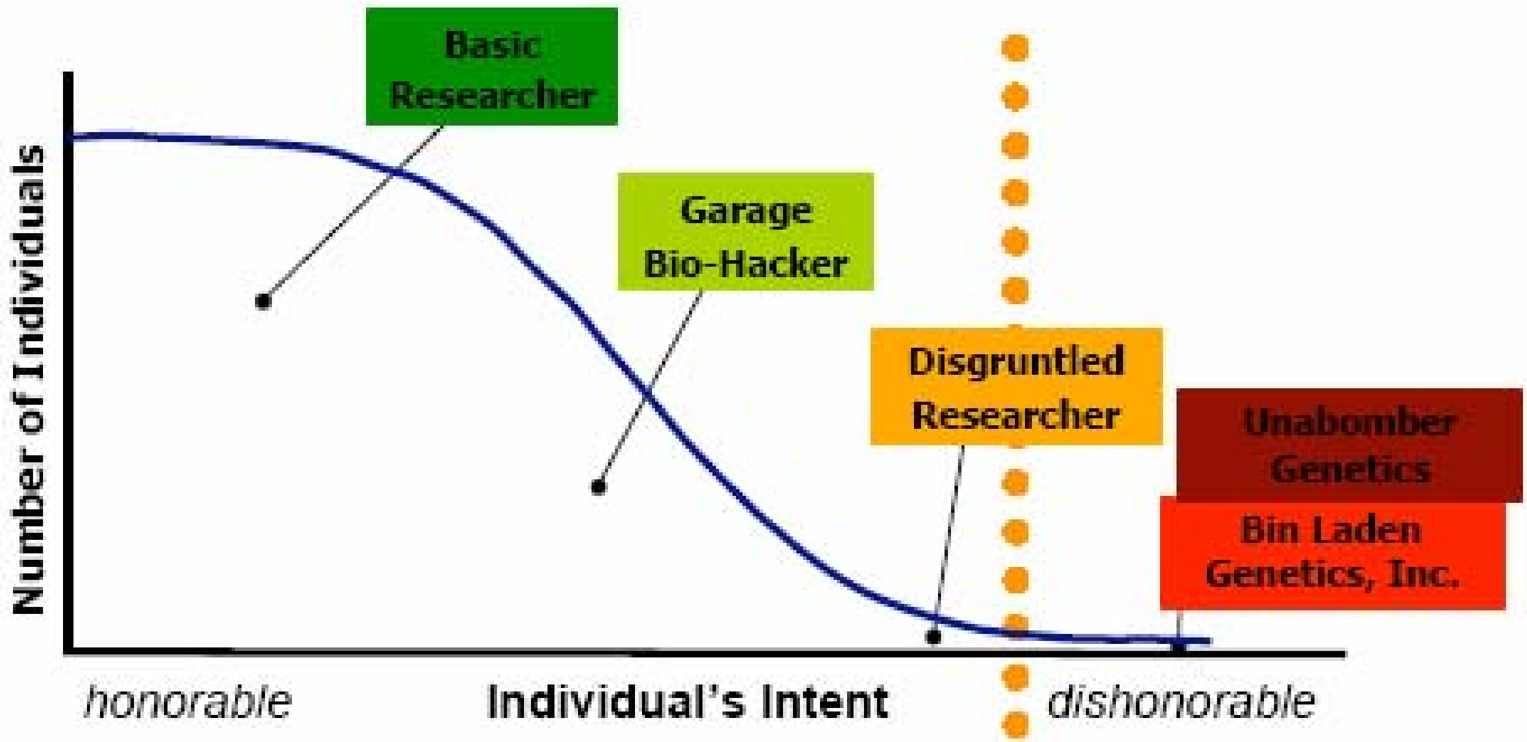
I am creating artificial life, declares US gene pioneer

- Scientist has made synthetic chromosome
- Breakthrough could combat global warming

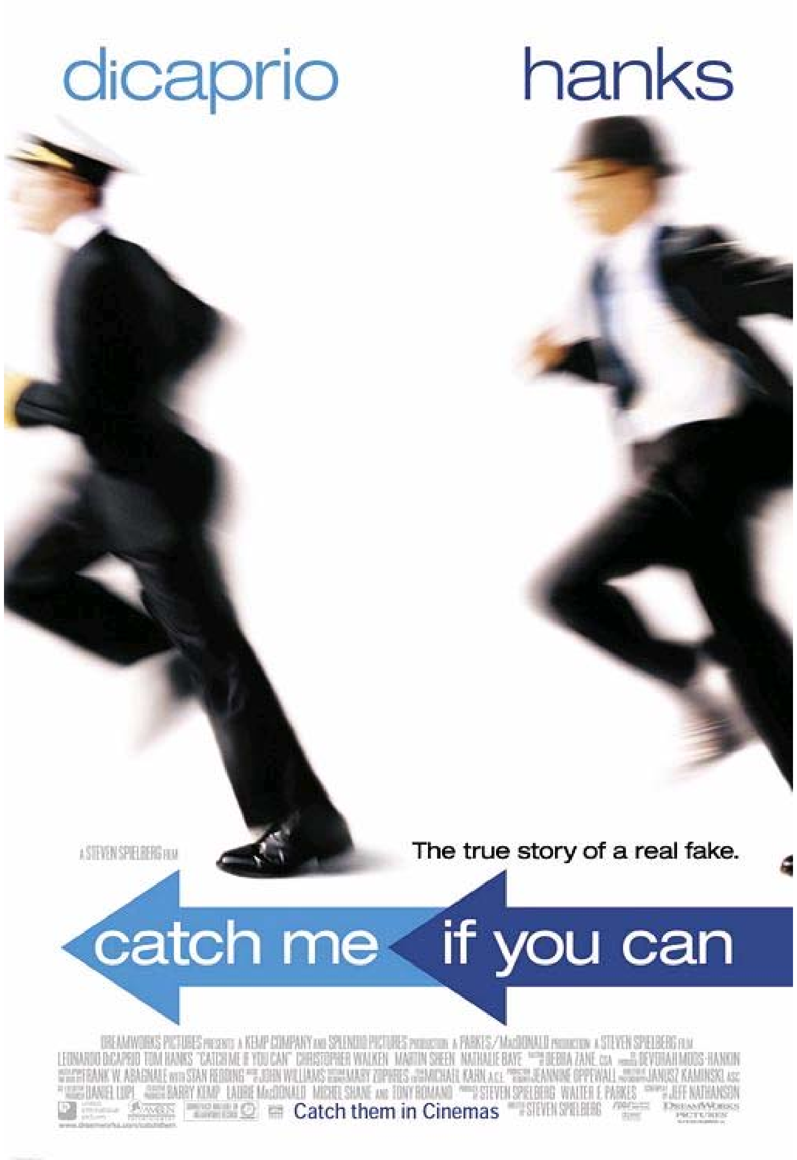
Suite of solutions



SYNTHETIC GENOMICS | *Options for Governance*

Michele S. Garfinkel, *The J. Craig Venter Institute, Rockville, Maryland;* **Drew Endy,** *Massachusetts Institute of Technology, Cambridge, Massachusetts;* **Gerald L. Epstein,** *Center for Strategic and International Studies, Washington, District of Columbia and* **Robert M. Friedman,** *The J. Craig Venter Institute, Rockville, Maryland*

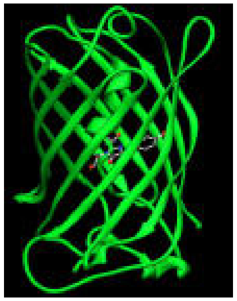
October 2007



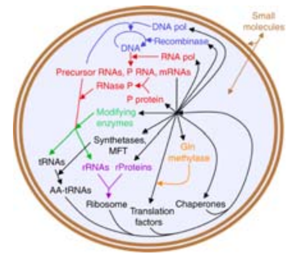
Q&A: Former fraudster Frank Abagnale offers IT security advice

Next generation biotechnology

Applications dependent on synthetic capabilities



single genes*



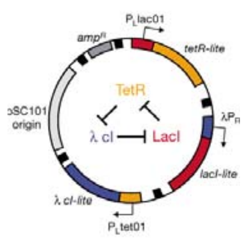
minimal life

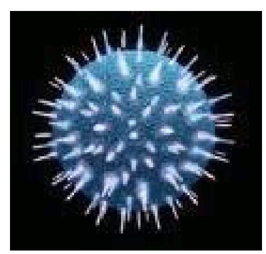
base pairs

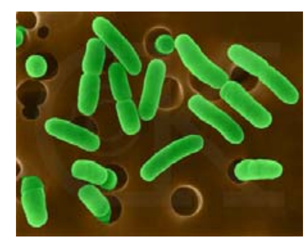
10^2 10^3 10^4 10^5 10^6 10^7

genetic circuits, viruses, GEMs

<u>Engineered organisms</u>







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AMYRIS BIOTECHNOLOGIES

Realizing the Promise of Synthetic Biology

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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.


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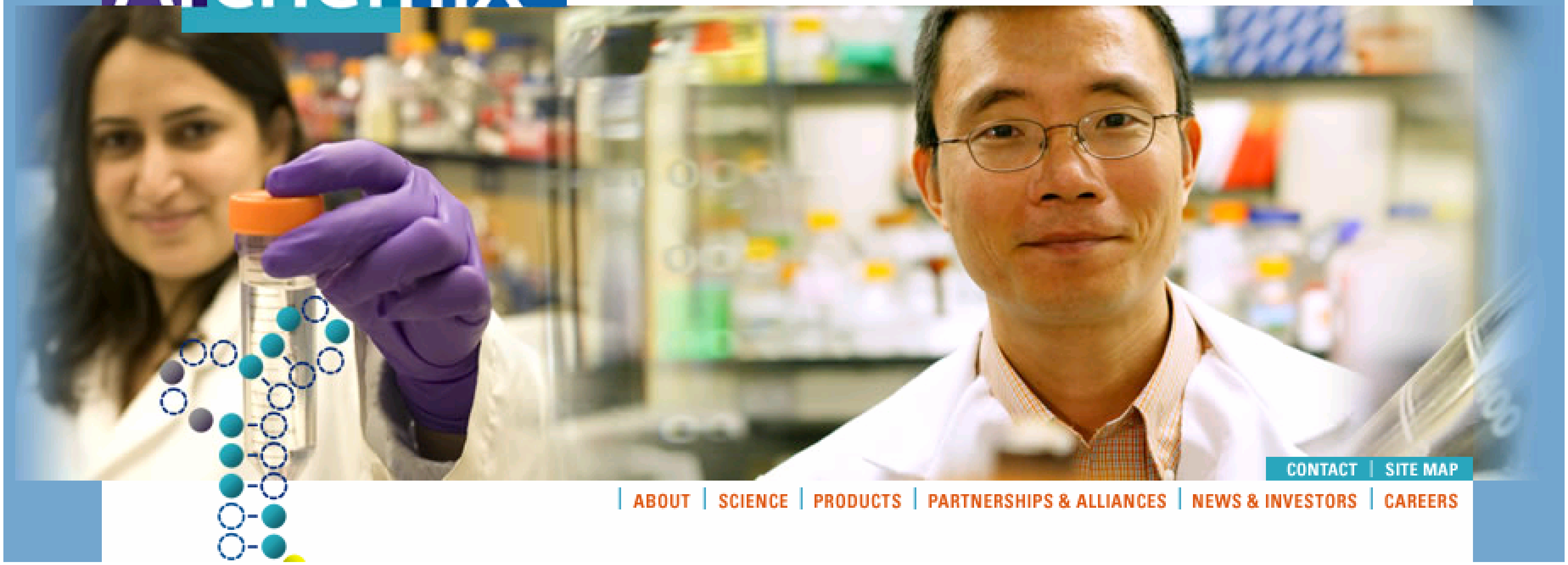
Constructed Operons & Operon Variant Libraries
Genomic Engineering

Archemix

The Aptamer Therapeutics Company™



Investors

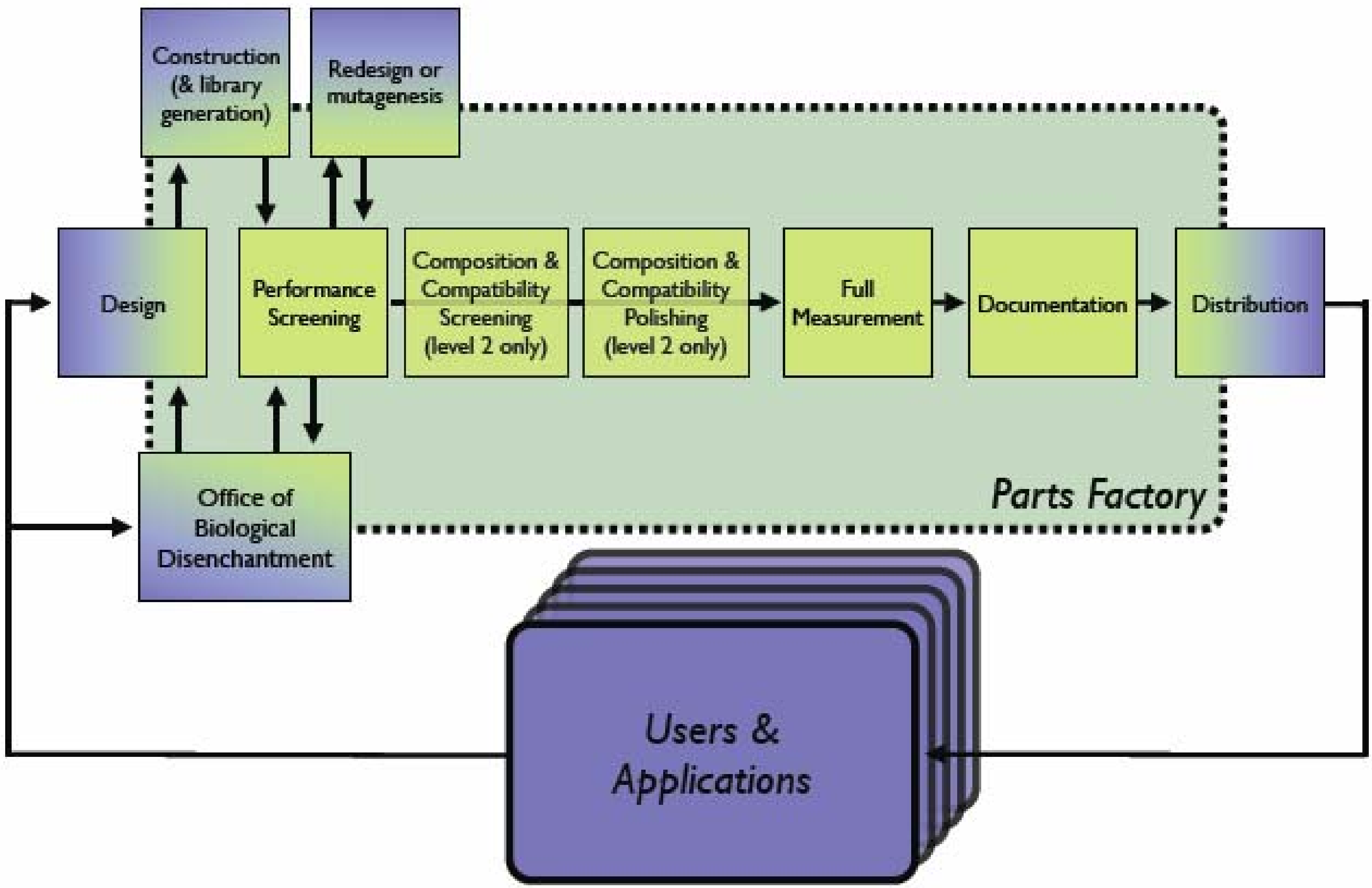
Funded by a syndicate of well-respected, top-tier venture capital firms, Archemix has raised over $100 million to date.

The Series B round ($53M, completed 1Q 2004) was led by Highland Capital Partners, and included all of the Series A investors and Athenian Venture Partners.

The Series A round ($52M, completed 3Q 2002) included lead investors Atlas Venture, Prospect Venture Partners and SV Life Sciences. Other investors included Rho Ventures, Care Capital, MDS Capital, POSCO BioVentures, and US Trust Private Equity.

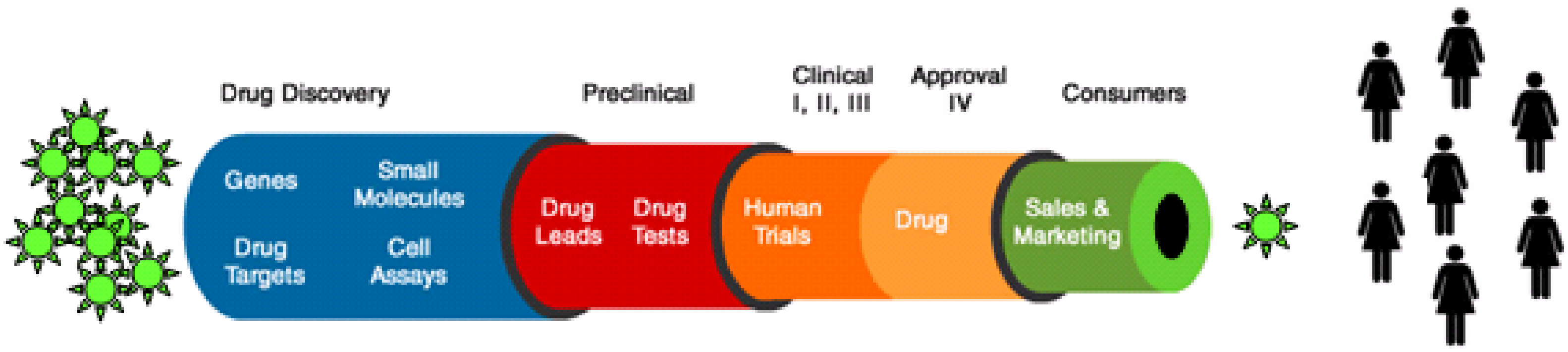
Archemix and Merck KGaA Sign Strategic Alliance

Collaboration to Focus Primarily on Cancer Therapeutics Using Novel Aptamer Technology



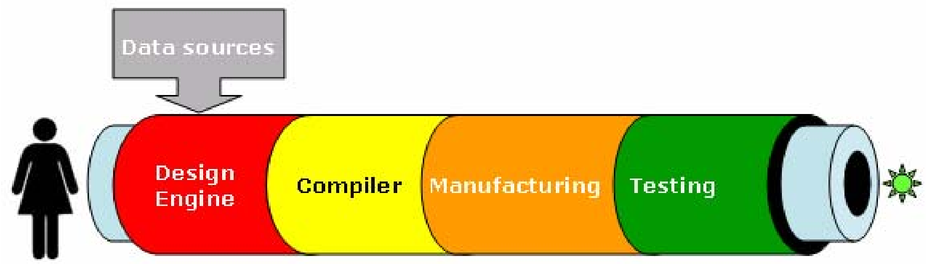
Construction (& library generation)
Redesign or mutagenesis
Design
Performance Screening
Composition & Compatibility Screening (level 2 only)
Composition & Compatibility Polishing (level 2 only)
Full Measurement
Documentation
Distribution
Office of Biological Disenchantment
Parts Factory
Users & Applications

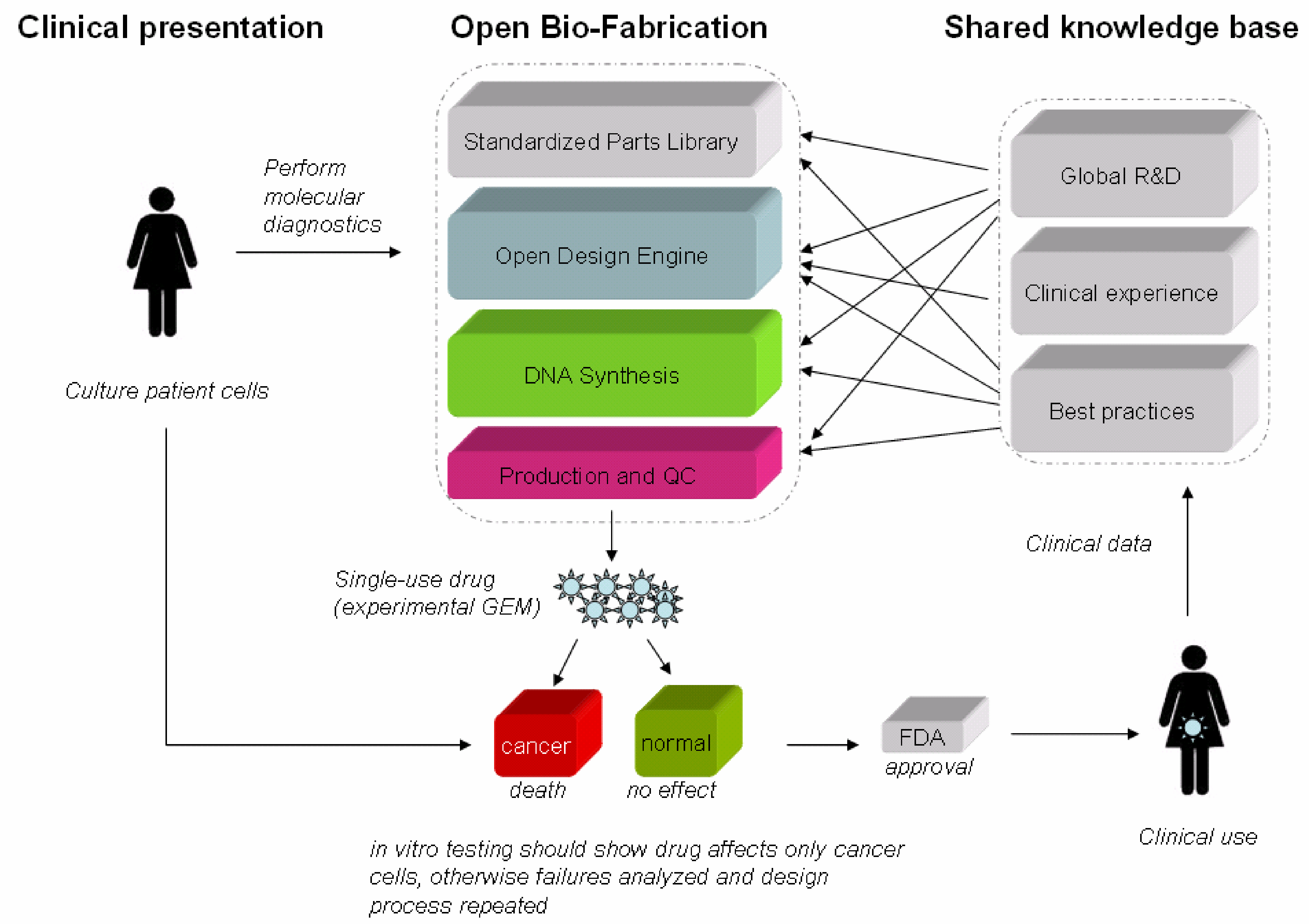
Toward a New Drug Development Pipeline Suitable for Personalized Cancer Therapeutics



Ideally, a next-generation pipeline for effective cancer drugs would:

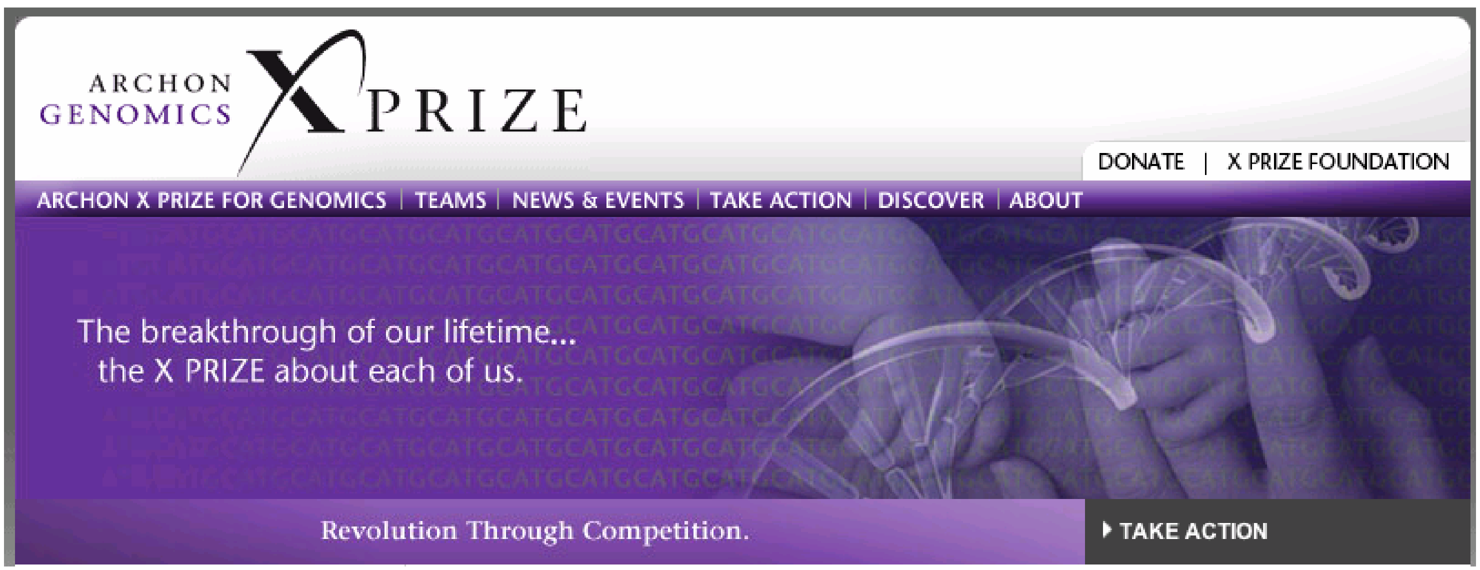
- As an output, produce personalized medicines
- Be able to produce a targeted medicine for every cancer, newly diagnosed or recurring
- Allow for rapid and sustainable development of these outputs
- Have favorable drug development economics, ie. the cost of producing drugs decreases over time
- Make a failure of any drug in the pipeline a trivial event
- Be able to grow in output capacity to satisfy the needs of a global market
- Continuously incorporate the latest understanding and data from molecular biology, oncology, and related sciences, plus growing clinical experience with personalized medicines
- And, finally, ensure the highest possible standards of safety and oversight





Pinkarmy.org


New Individual Human Diploid Sequence >>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Revolution Through Competition.
TAKE ACTION

Google™

Google Health Wants to Digitize Your Medical Records

Google Health, Mayer says, wants to digitize your health records—x-rays, immunization records, every surgery, every doctor visit, everything. And she wants you to be able to take it with you anywhere in the world, perhaps on some kind of external device. That information will be protected by a password, but you will also be able to share it with your friends and family.

23andMe

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- Tear down barriers between professions and institutions and think global in scale
- Move aggressively to educate!
- Develop core resources (informational and physical)
- Choose exciting and valuable applications
- Support next-generation industry

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Alberta Ingenuity operates
the Alberta Heritage Foundation for Science and Engineering Research,
a $1 billion endowment to support research.

Ingenuity

NEWS

Ingenuity launches bold new $100 million research program
October 10, 2007 - Ingenuity Accelerators focus on ensuring future prosperity of the province.