iGEM Program Overview

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International Genetically Engineered Machines Competition

Outline

- Overview of fundamental drivers
- How iGEM came to exist
- The goals of the program
- iGEM growth and success
- Reasons to participate
- Speculate on the future of iGEM and synthetic biology

R & D

What is biological research?

- Study of living things
  - Macro: description and classification of organisms
  - Molecular: description and classification of genomic data, proteome data, regulatory networks, signaling networks, etc.

Reverse Engineering

Reverse engineering is essentially science, using the scientific method.

Sciences such as biology and physics can be seen as reverse engineering of biological 'machines' and the physical world respectively.

Attempt to go backwards through the development cycle – “top down” approach

Source: wikipedia

Scientists hack

Tools of the trade

Classical

Restriction enzymes
Plasmids
Hybridization
PCR
DNA sequencing
Light microscopes, EM, SEM
Pipettes, microtubes
uL volumes
Lab notebooks
Journal artices
Etc.

Refinements

Automated DNA sequencing
Software-based data analysis and modeling
Parallelized, HTS experiments
nL or smaller volumes
Higher resolution vision – single molecule, real time
Robots and computers
Internet-based data sharing, eg. wikis, open access journals

Reverse engineering results in massive amounts of data

Systems biology *attempts to integrate this and create comprehension to facilitate research and development*

Easier to produce and collect data than to make sense of it.

We are just beginning to learn about microbial and molecular world.

What is biological engineering?

In a word: Development

Very different mindset, culture, skills required to do development.

Not much exposure to development in most academic science settings.

Engineering Foundation

"directed evolution"

refinement

Even more success

refinement

More success

refinement

Some success

complexity

- Electronics
- Software
- Aeronautics
- Structures
- Materials
- Automotives

We *need* to engineer

- Apply knowledge gained from research to engineer the world around us
- Engineered structures and systems have defined characteristics, are dependable, make us feel in control
- Necessary to develop projects beyond the capabilities of the individual
- Today, almost everything around us is heavily engineered
- The one major exception is living organisms

To the engineer, past BE efforts inefficient

Struggle
Limited success
More struggle

Haphazard success

Problems compounded by proprietary IP

BE seen as “fuzzy”, risky, even *dangerous*

Alberta January 2007

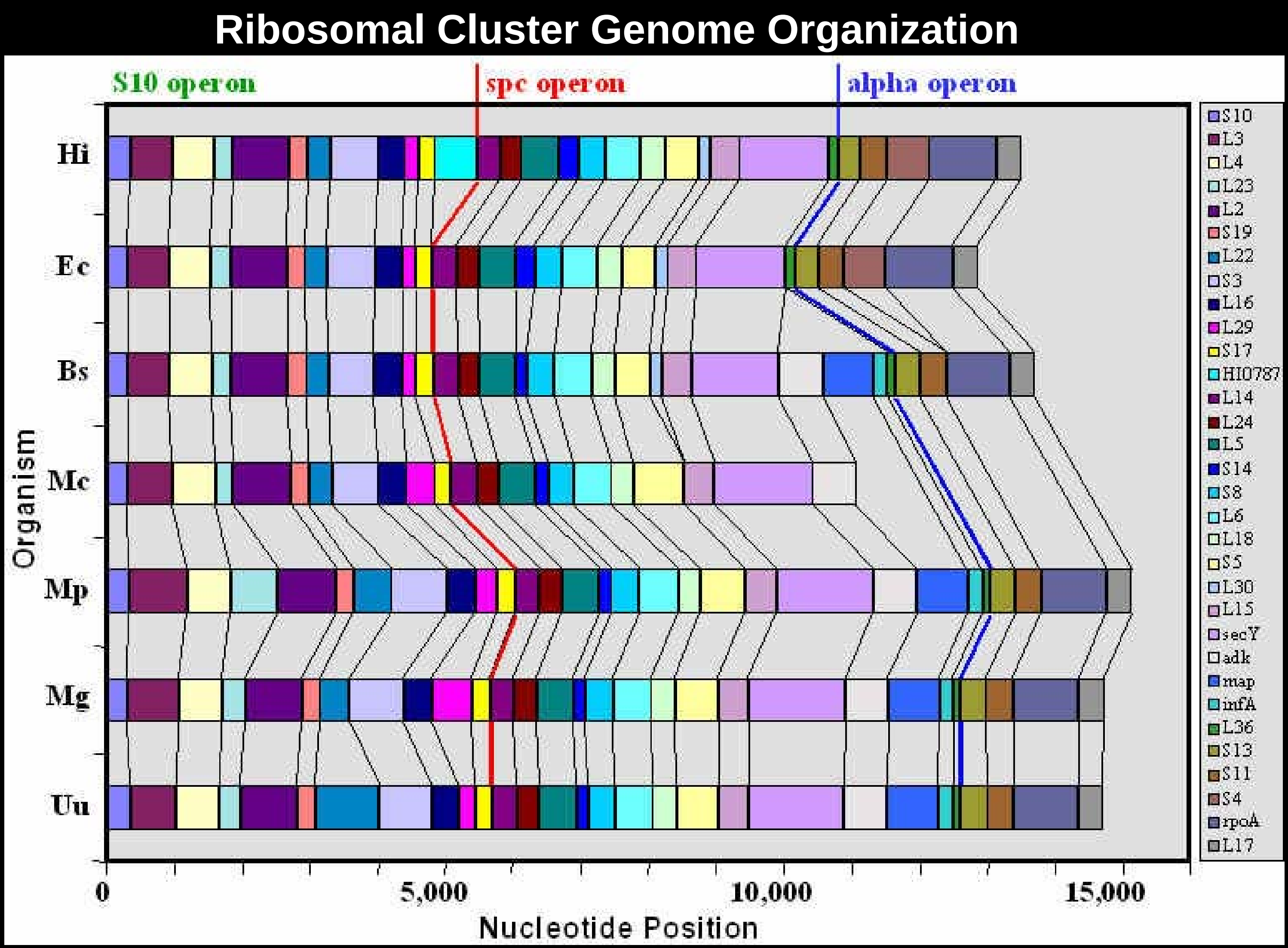
Key question:

Can biological engineering be made more robust and reliable and easy?

Synthetic Biology

- Founded on DNA synthesis
- DNA code can result in the creation and operation of virtually any biological molecule, process, bounded set of processes (organism), or ecology
- Ability to create DNA *de novo* results in a true programming language for biological machines

Existing genetic code is modular



Problem:

We didn't write existing DNA code or the design the cellular processors on which it runs.

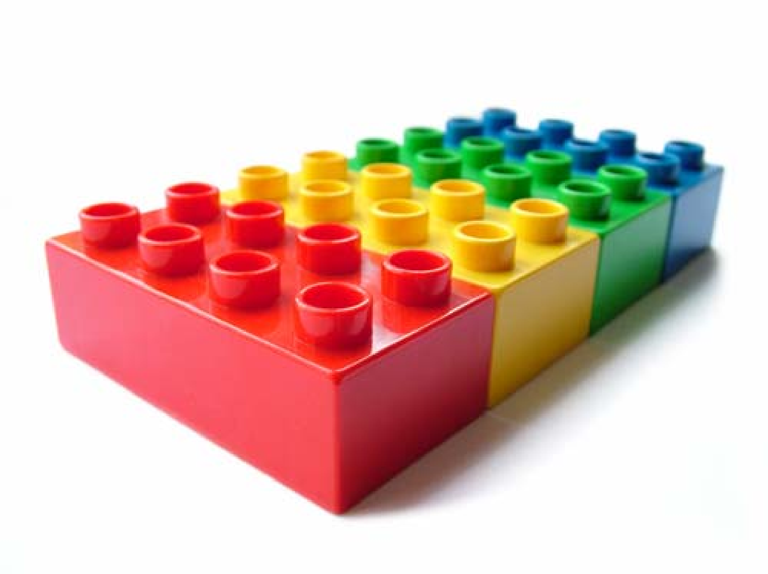
Evolved by natural selection, these programs and systems are selected for dynamic flexibility.

Not ideal for engineering purposes, which above all requires stable performance.

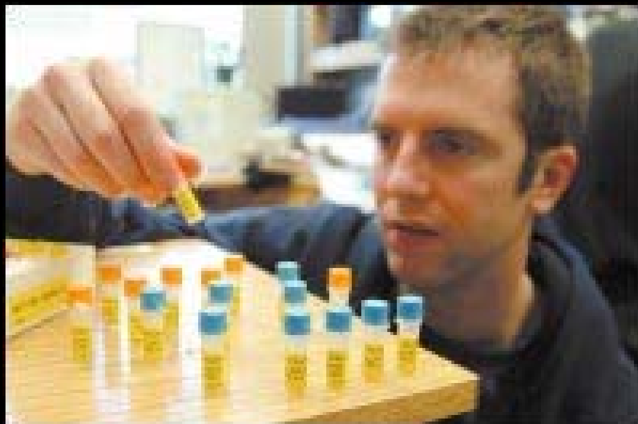
We can't *fully understand* natural biological systems.

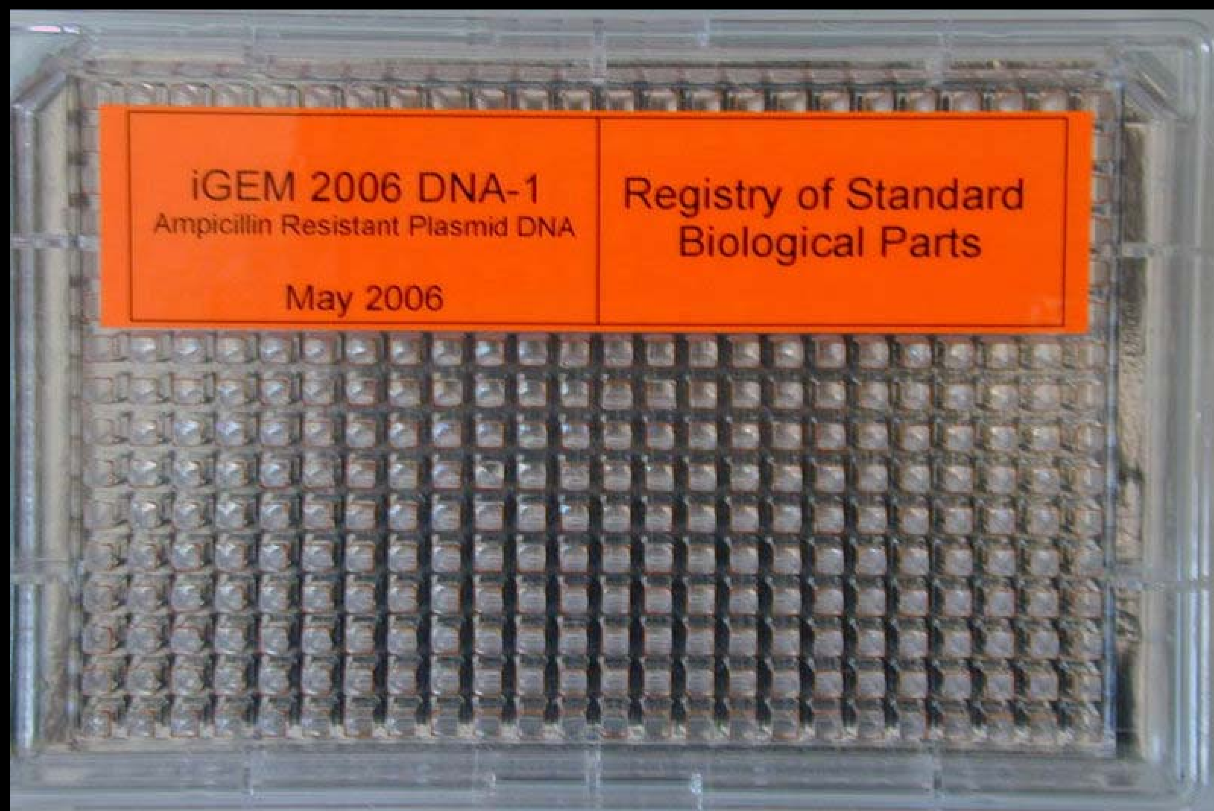
Solution: make new modules

- Defined
- Multi-purpose
- Flexible
- Potential for unlimited applications

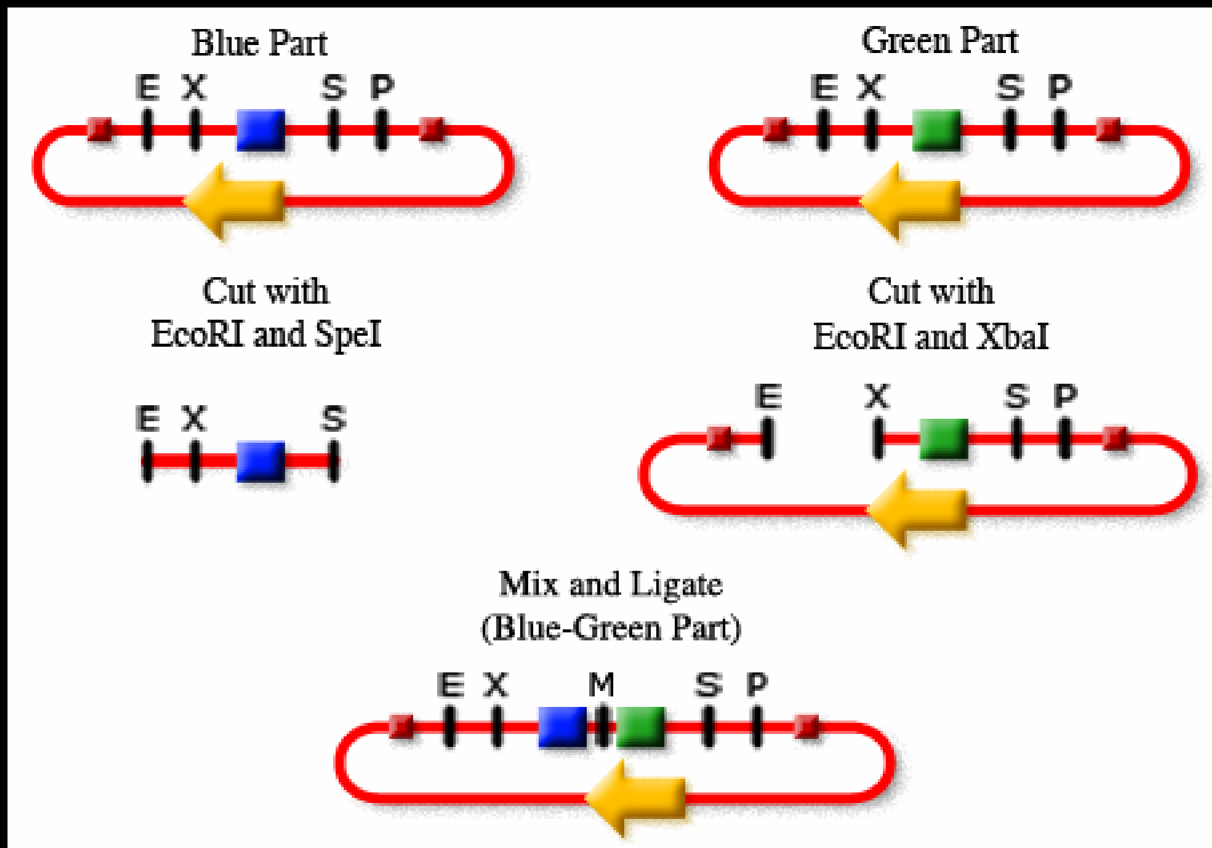


Inspiration for the “Bio-brick”



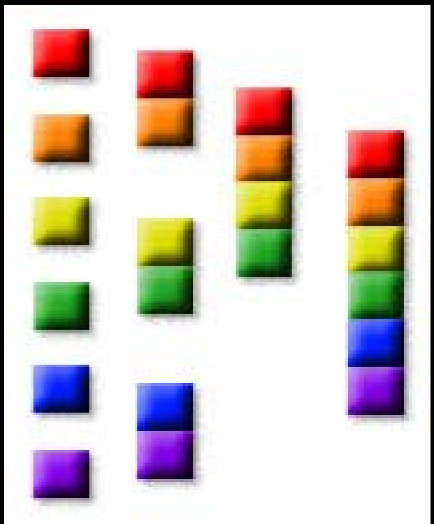

iGEM 2006 DNA-1
Ampicillin Resistant Plasmid DNA
May 2006
Registry of Standard
Biological Parts

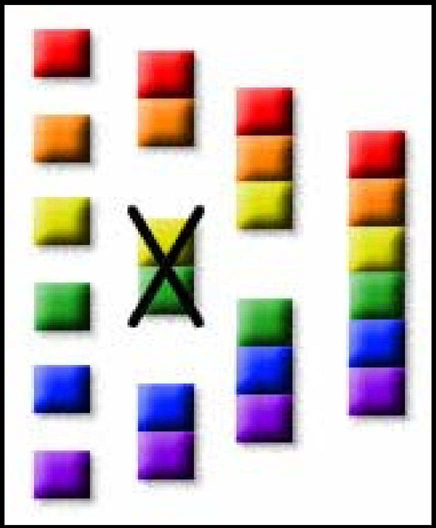
And a way to assemble them…



"standard assembly"

Rolling Assembly





Rolling standard assembly allows multiple assembly lines to be pursued to make the final product. This makes assemblies fault tolerant. Process is iterative and can be automated.

Robotic Bio-Brick Assembly

Bio-Bricks allow:

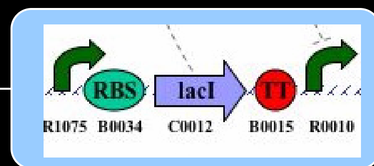
- **Standardization**
  - Defined parts, with specifications, facilitate broad collaboration
- **De-coupling**
  - Complex problems can be broken into smaller problems, allowing parallel efforts
- **Abstraction**
  - Tiers complexity, permits specialization

Abstraction Hierarchy

Systems

Multiple devices with a defined function

Device



Multiple biobricks with a defined function

Part

Basic biobrick, eg. protein coding region

DNA

atgtggaggtctgtatcatctattggactc

“Source code”

Approach:

1. Seed a library of parts

2. Encourage creativity

Use "open source"

- Consistent with academic principles
- Facilitates discussion and exchange
  - Lubricates dissemination of ideas
  - Sharing of reagents and tools
  - Identifies solutions to problems or "bugs"
- Decreases need to re-invent
  - Facilitates collaborations and communities
- Less paperwork and bureaucracy
- Result: maximum rate of innovation and evolution

Make it fun

- “Play” vs. “work”
- We like to play with others
- We like to share accomplishments
- We like success
- We like to impress
- We like to win prizes
- Therefore: create a structure that fosters collaboration and competition

iGEM

iGEM Goals

- Enable the systematic engineering of biology
- Promote the open and transparent development of tools and reagents
- Help construct a society that can productively apply biological technology

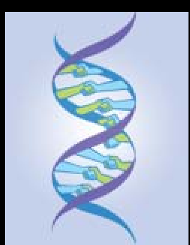
The iGEM Challenge

- Student-based
- Disseminate philosophy
- Inspire development of “cool” ideas
- Pool parts and expertise
- Promote sharing and community
- Encourage competition
- Require participation
- Drive results

Three pillars of iGEM

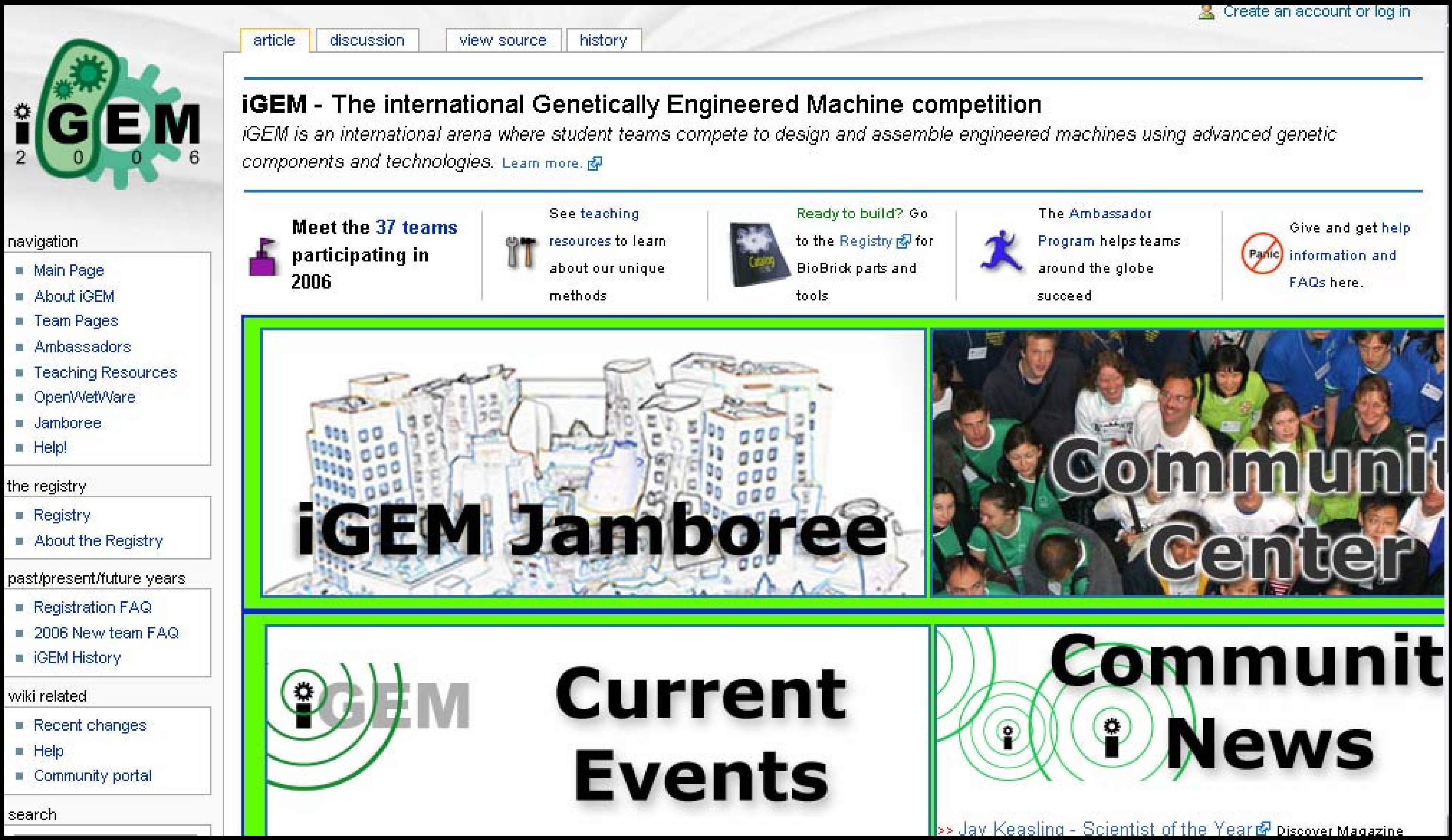
- **The iGEM wiki**
  - Share philosophy, ideas, reagents, current info, news, biographies, stories, etc.

- **The Registry**
  - Technical data, specifications, designs, test data, etc.



- **OpenWetWare**
  - Transitions iGEM alumni to the synthetic biology professional community

iGEM Wiki



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Ambassadors
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Jamboree
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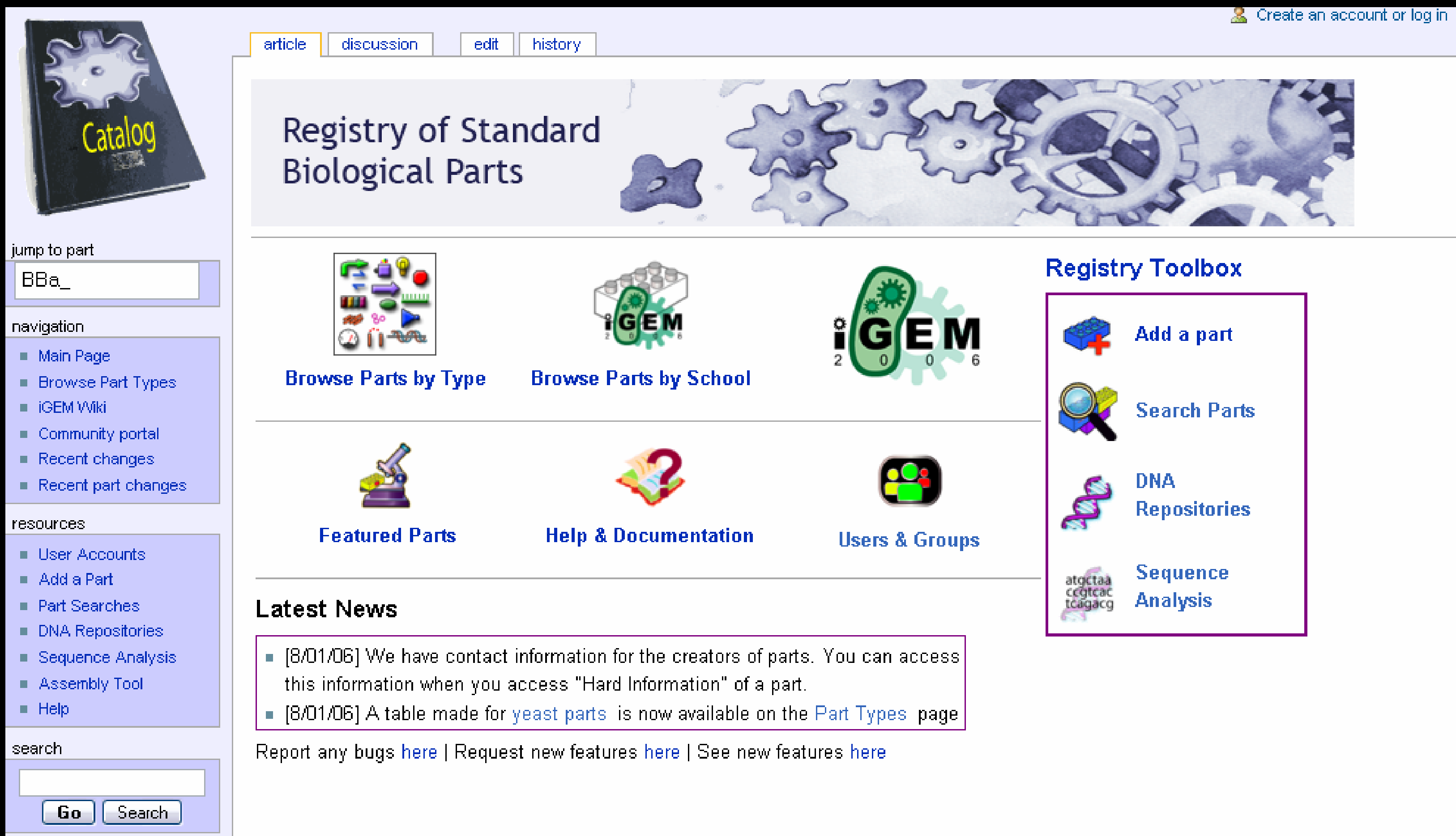
the registry
Registry
About the Registry
past/present/future years
Registration FAQ
2006 New team FAQ
iGEM History
wiki related
Recent changes
Help
Community portal
search
iGEM - The international Genetically Engineered Machine competition
iGEM is an international arena where student teams compete to design and assemble engineered machines using advanced genetic components and technologies. Learn more.
Meet the 37 teams participating in 2006
See teaching resources to learn about our unique methods
Ready to build? Go to the Registry for BioBrick parts and tools
The Ambassador Program helps teams around the globe succeed
Give and get help information and FAQs here.
iGEM Jamboree
Communit Center
iGEM Current Events
Communit News
>> Jay Keasling - Scientist of the Year Discover Magazine

Registry


Catalog
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Registry of Standard Biological Parts
jump to part
BBa_
navigation
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Sequence Analysis
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Search
Browse Parts by Type
Browse Parts by School
iGEM 2006
Featured Parts
Help & Documentation
Users & Groups
Registry Toolbox
Add a part
Search Parts
DNA Repositories
Sequence Analysis
Latest News
[8/01/06] We have contact information for the creators of parts. You can access this information when you access "Hard Information" of a part.
[8/01/06] A table made for yeast parts is now available on the Part Types page
Report any bugs here | Request new features here | See new features here

Available Transcriptional Terminators

Show 33 more parts — Edit

-?-		Name	Description	Direction	Reversed Version	Biology	Efficiency * Fwd.	Efficiency * Rev.	Length
A	W	BBa_B0011	Terminator (luxICDABEG, +/-)	Bidirectional	BBa_B0021	LuxIA	0.419	0.636	46
A	W	BBa_B0014	Terminator (B0012, B0011)	Forward	BBa_B0024	B0012, B0011	0.604		95
A	W	BBa_B0015	Terminator (B0010, B0012)	Forward	BBa_B0025	(B0010, B0012)	0.984	0.295	129
A	W	BBa_B0021	Terminator (luxICDABEG, +/-)	Bidirectional	BBa_B0011	LuxIA (reversed)	0.639	0.419	46
A	W	BBa_B0025	Terminator (Reverse B0015)	Reverse	BBa_B0015	(B0010,B0012) reversed	0.295	0.984	129
A	W	BBa_J52016	Eukaryotic terminator						238
A		BBa_B0010	Terminator (T1)	Forward	BBa_B0020	T1			80
A	X	BBa_B0012	Terminator (T7 TE)	Forward	BBa_B0022	T7 TE	0.309	-0.368	41
A	X	BBa_B0013	Terminator (T7 TE, +/-)	Bidirectional	BBa_B0023	T7 TE	0.6	-1.09	47
A		BBa_B0017	Terminator (B0010, B0010)	Forward		B0010.B0010			168
A	X	BBa_B0022	Terminator (Reverse B0012)	Reverse	BBa_B0012	T7 TE (reversed)	-0.368	0.309	41
A	X	BBa_B0023	Terminator (Reverse B0013)	Bidirectional	BBa_B0013	T7 TE (reversed)	-1.09	0.6	47
A		BBa_B0024	Terminator (Reverse B0014)	Reverse	BBa_B0014	(B0012.B0011) reversed		0.604	95
A		BBa_B1004	Terminator (artificial, small, %T~=55)						34
A		BBa_J63002	yeast ADH1 terminator						225

* Click here for terminator measurement information.

Part:BBa_B0011

DNA Available
Experience: Works

Designed by Reshma Shetty

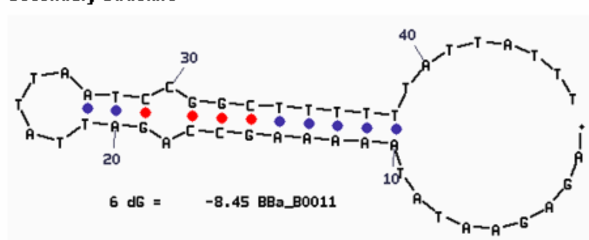
Entered: Antiquity

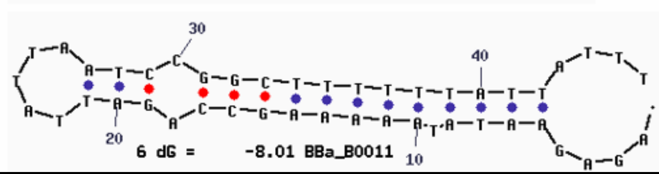
forward_efficiency	0.419
reverse_efficiency	0.636

Terminator (luxICDABEG, +/-)

- Bidirectional transcriptional terminator consisting of a 22 bp stem-loop.
- Appears to be a bidirectional terminator since it contains a string of T's on the direct strand after the stem loop and on the reverse strand before the stem loop. It is also found between two coding regions that point toward each other.

Secondary Structure





OpenWetWare

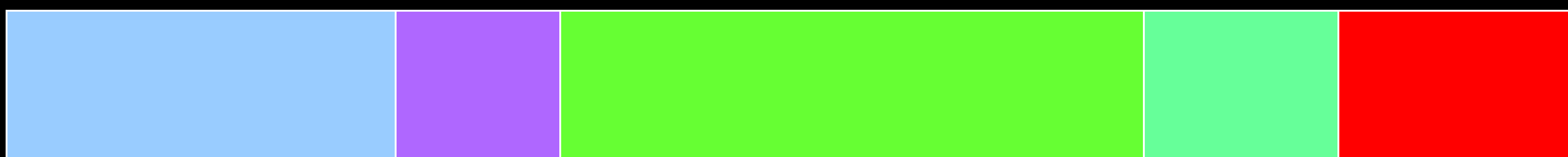
Growth of iGEM

- Founded 2003 as MIT IAP
- 2004 – 5 teams, all US based, “friendly”, 75+
- 2005 – 13 teams, including Cambridge, Zurich, Canada, 175+

Timeline

May
Project planning
Instructor training

Sept-Oct
Final experiments
Posters and presentations



Jan-April

Advertise, recruit, fundraise, journal club

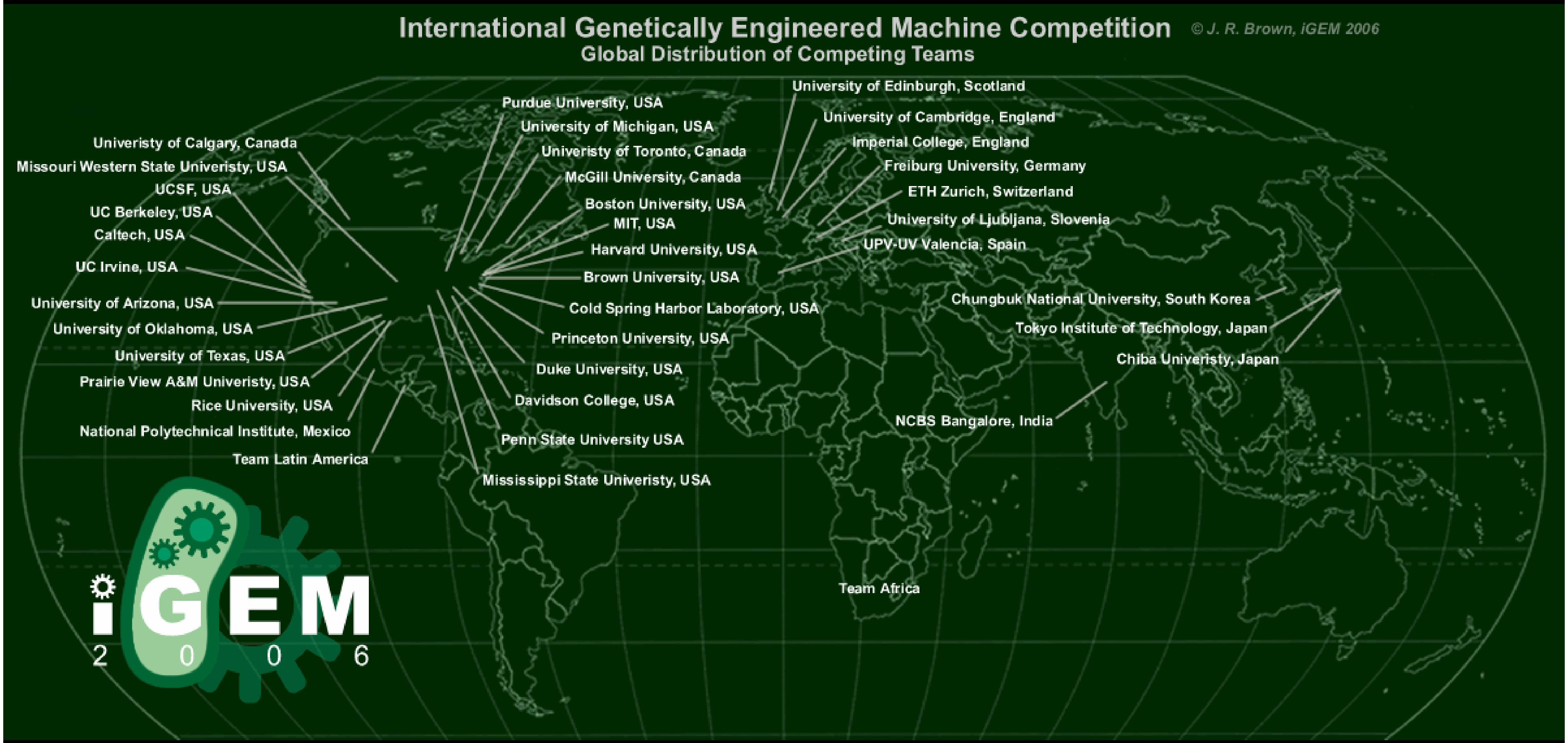
June-August

Majority of laboratory work performed

Nov-Dec
Jamboree
Wind up work
Planning for next year

Major Changes in '06

- Improved Registry (June) and iGEM wiki
- Shift to undergraduate focus
  - Great enthusiasm and able to take greater risks
- Formalized rules
  - Structured competition, qualifies for prizes
  - Unstructured competition, creates flexibility for unconventional teams, eg. high schools, to participate
- Ambassador program
  - Primarily for information exchange and technical support
- More documentation at all levels



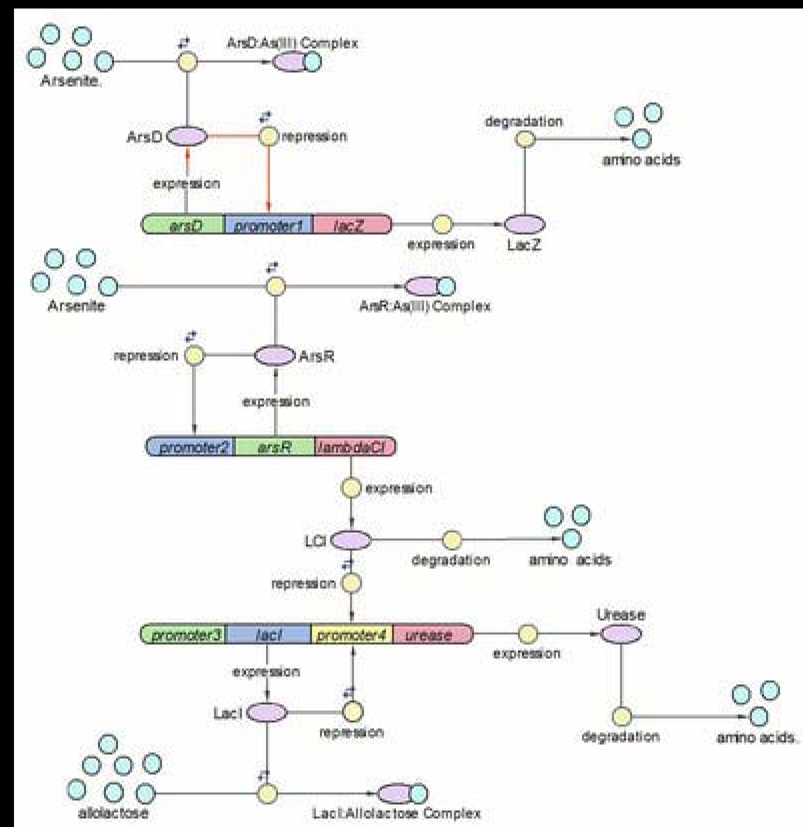
Alberta January 2007

Africa	Arizona	Bangalore	Berkeley [OWW]	Boston	Brown	Calgary [external]
Cambridge [external]	Chiba	Chungbuk	Davidson	Duke [external]	Edinburgh [external]	ETH Zurich
Freiburg	Harvard [OWW]	Imperial	Latin America	Ljubljana, Slovenia	McGill [external] [(francais)]	Michigan
Mississippi State	Missouri Western	MIT [OWW]	IPN_UNAM, México	Oklahoma	Penn State [OWW]	Prairie View
Princeton	Purdue	Rice	SF	Texas	Tokyo Alliance	Toronto

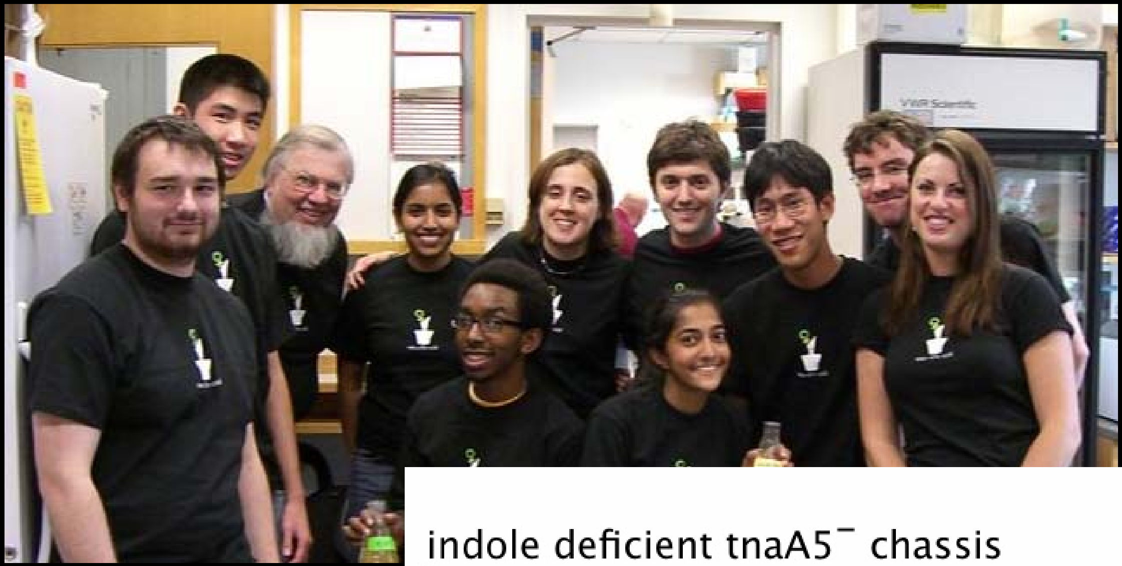
Growth of iGEM

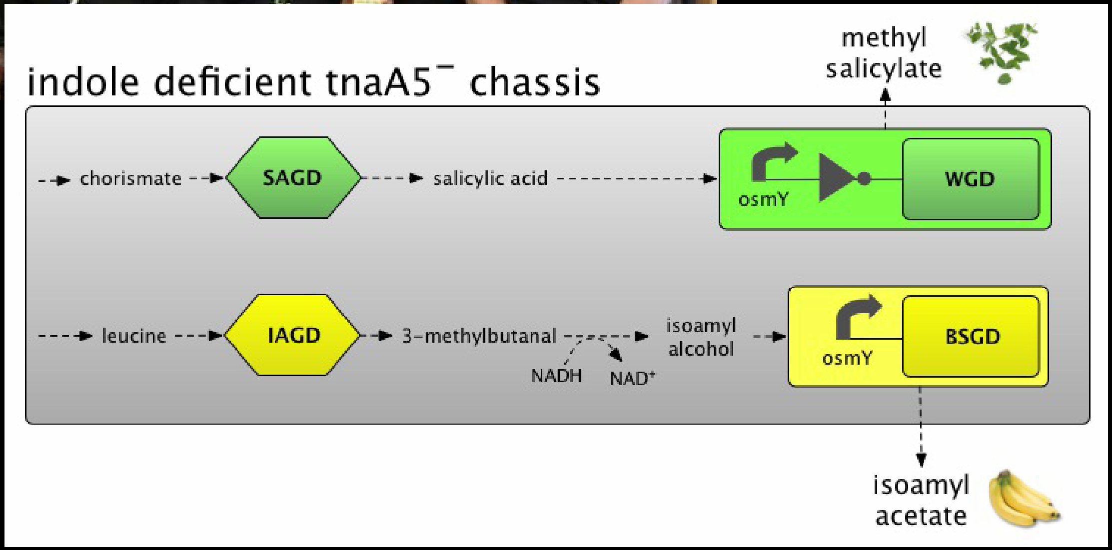
- 2006 – 37 teams, 15 countries, 450+
  - Sharp increase in global interest
  - 35,000 new hits on website since Jamboree
  - EU regional being established
  - China recruitment tour

Arsenic biosensor



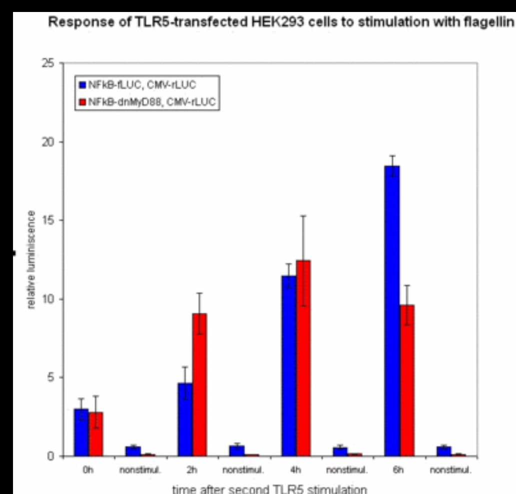
Smell Reporter system





2006 Grand Prize Winner

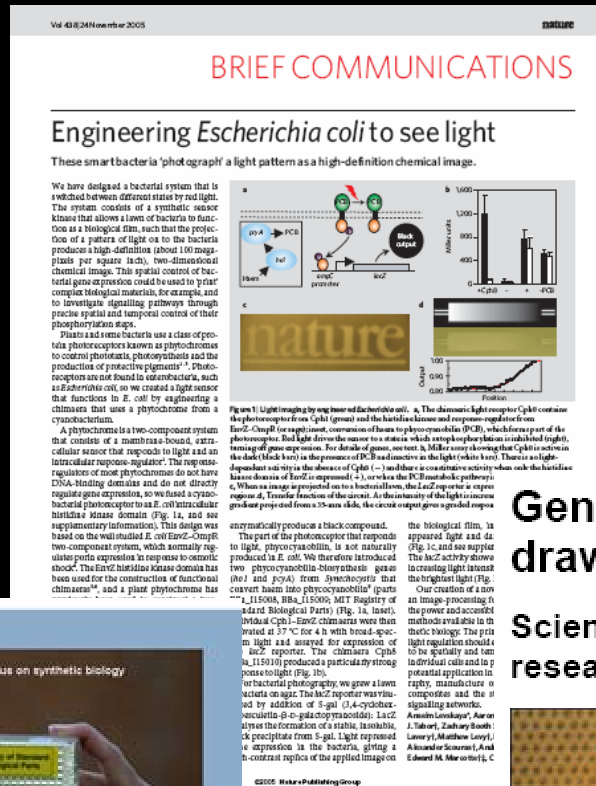
iGEM 2006
Slovenija




CSSI
MIT

Early indicators of success

- Expanding collection of parts
- Large public interest
- Growing scientific interest
- Government recognition
- Extremely short development times
- Successful projects
- Publications
- Increasing financial support
- Low attrition – most participating schools return



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)

iGEM 2007

- On target for 100 teams, 1400 people
- Regional organizations are forming
- Podcasts, videos
- Expanding documentation
- Team portals
- Tighter competition rules
  - Some structure helped groups to create and meet goals

Reasons to participate in iGEM

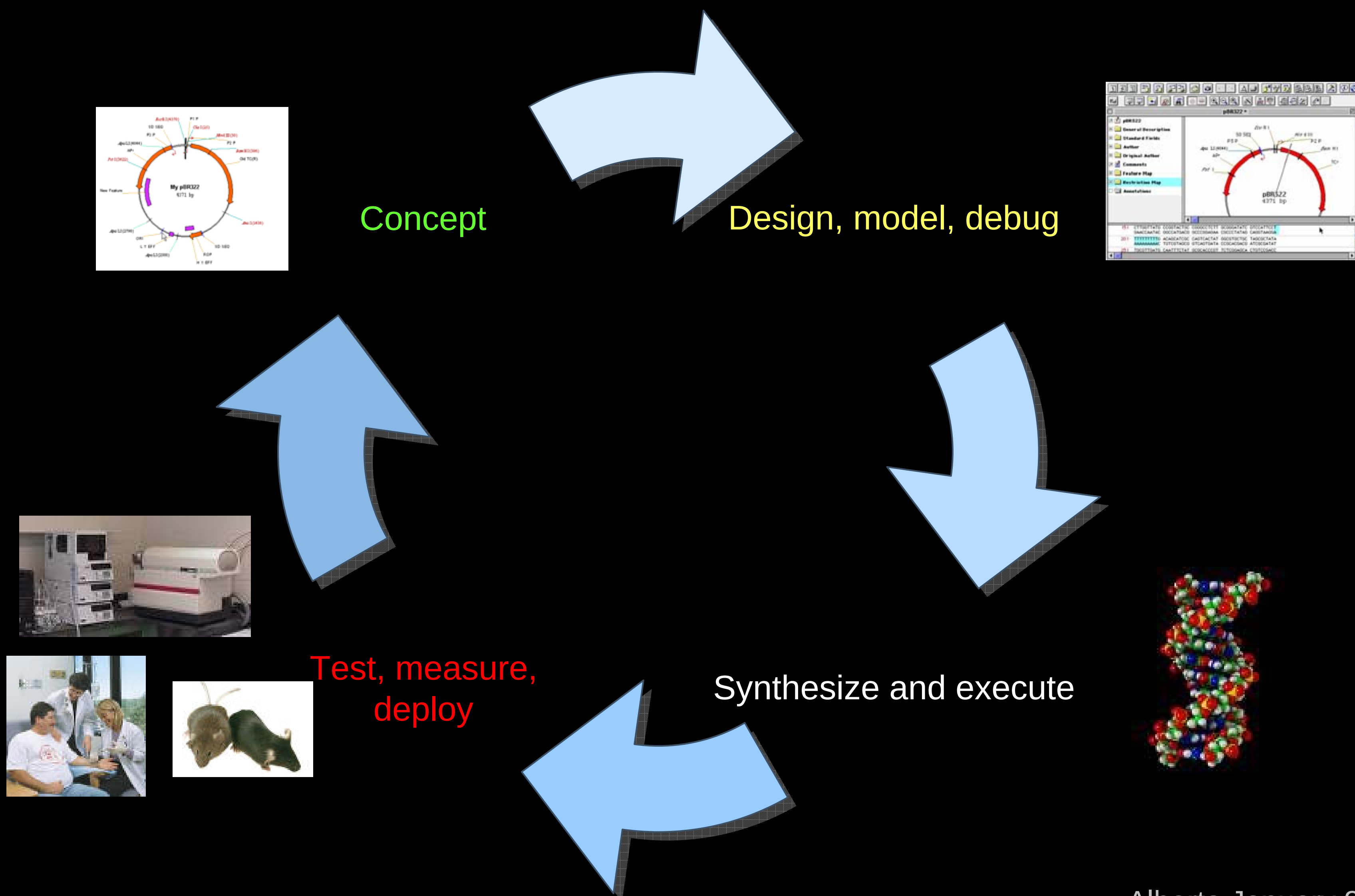
- Early opportunity to explore SB at low risk
- Access to top SB leaders worldwide
- Reach through to previous years’ knowledge and parts (valued in $M’s) for relatively small investment
- Membership in a large and growing community
- High visibility
- Opportunities for funding
- Exposure to societal issues created by advanced biotechnologies
- Chance to demonstrate creativity, skills, and leadership
- Prizes and trophies

IGEM *is now recognized as the premier undergraduate educational program for synthetic biology*

Just the beginning…

- iGEM growth expected to stay strong
- DNA synthesis costs falling
- Synbio community growing quickly
  – Academia is re-tooling
- Synbio industry is budding
  – Codon Devices
  – Synthetic Genomics
  – Amyris
  – Coda

Synthetic biology workflow will become increasingly rapid and automated



Massive potential

Free your mind

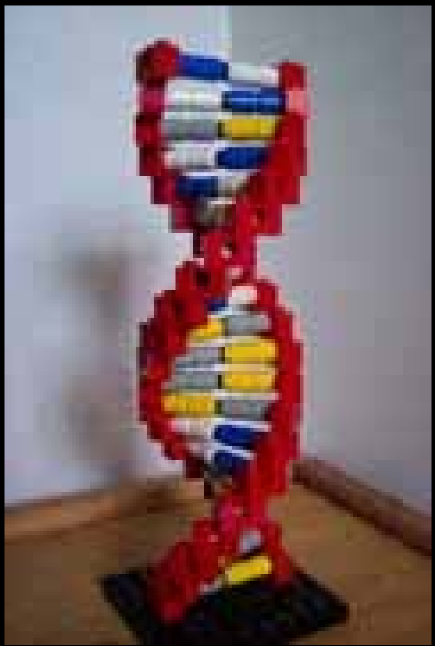
- DNA code be used to make *anything* biological
- 100 million or more species in nature
- Given this proven biodiversity, the main barrier is our own creativity
- Entering a period of massive new speciation, driven by human wants and needs, and evolving at the rate of human technology (2x:18m)

Why is synbio still under the radar?

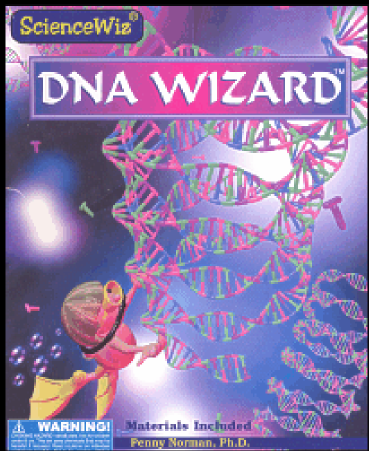
- If reverse engineering is science, then engineering is reverse science

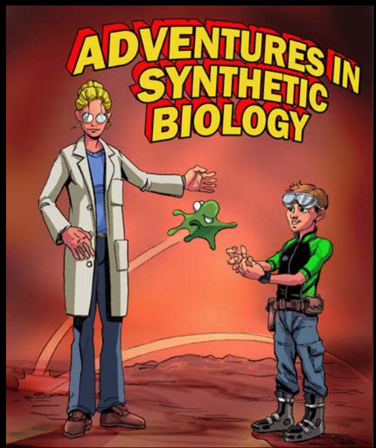
- Scientists can find biological engineering counter-intuitive

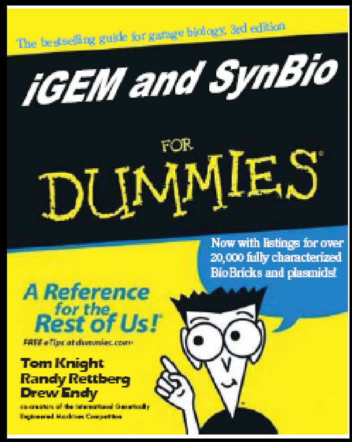
Just as Lego has continued to evolve…



So will iGEM and synthetics







- Applied by younger scientists
- Synthetic bacteria, other organisms
- Biotech 2.0

However…

"With great power comes great responsibility"

"We scare people" – Endy 11/06

If iGEM and synbio are to thrive, we must *continually reinforce the positive applications* of this technology

Thank you