Synthetic Biology
A Trip Around the Neighborhood

U.S Department of Agriculture
January 25, 2011

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Director
Science and Technology Innovation Program
Woodrow Wilson International Center for Scholars

Synthetic BIOLOGY PROJECT

What is It?

"Synthetic biology is a) the design and construction of new biological parts, devices and systems and b) the re-design of existing natural biological systems for useful purposes."

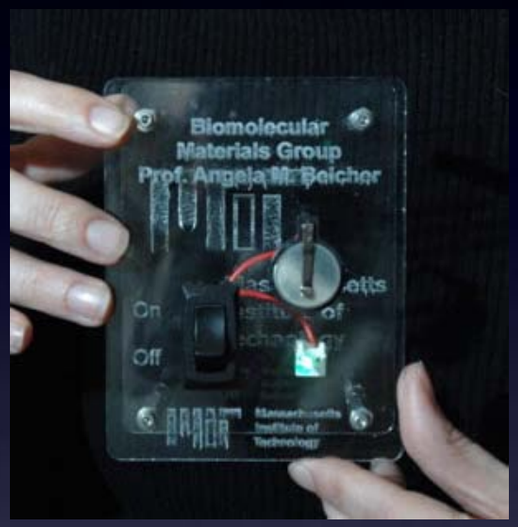
"Synthetic biology aims to design and build new biological parts and systems or to modify existing ones to carry out novel tasks."

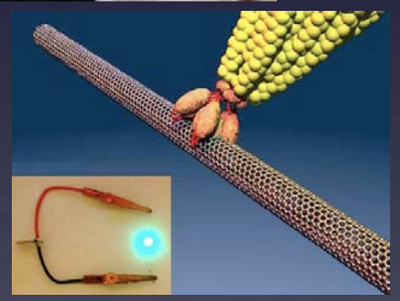
"Synthetic biology is the engineering of biological components and systems that do not exist in nature and the re-engineering of existing biological elements;

"Our overall long term goal is to help make biology easy to engineer, an area of research known as synthetic biology."

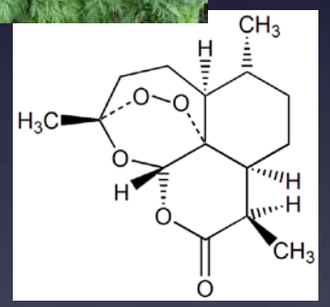
“The biological world is displacing the machine as a general model of design.”

Neri Oxman, MIT Media Lab





Build batteries with viruses



Manufacture drugs with yeast

Synthetic Biodiesel
2.4 million gal/yea

Synthetic Biology: Is This Real?

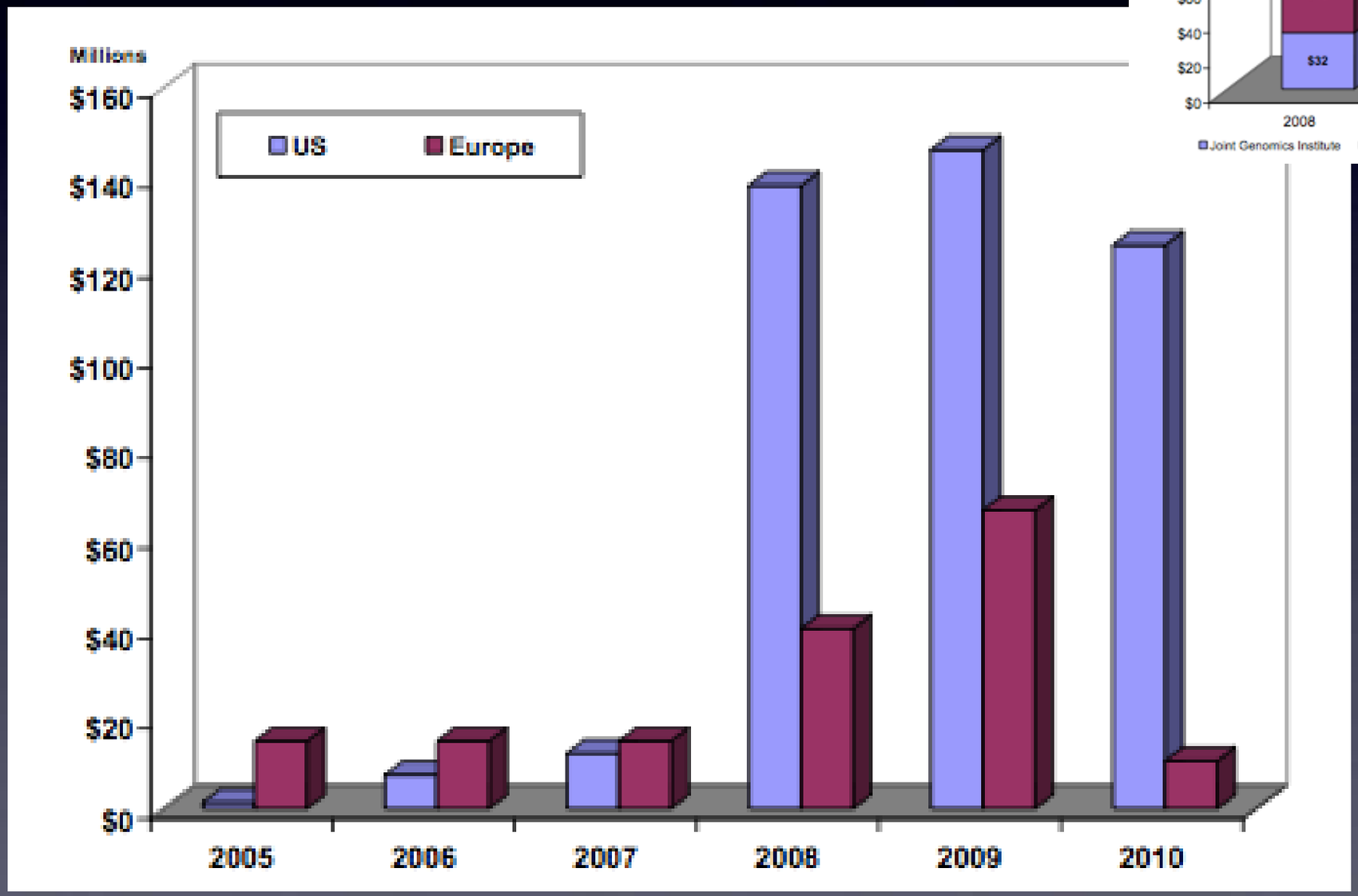
Estimates have placed the current annual synthetic biology research market at $600 million, with the potential to exceed $3.5 billion over the next decade.[1] One-fifth of the chemical industry (currently worth $1.8 trillion) could be dependent on synthetic biology by 2015.[2]

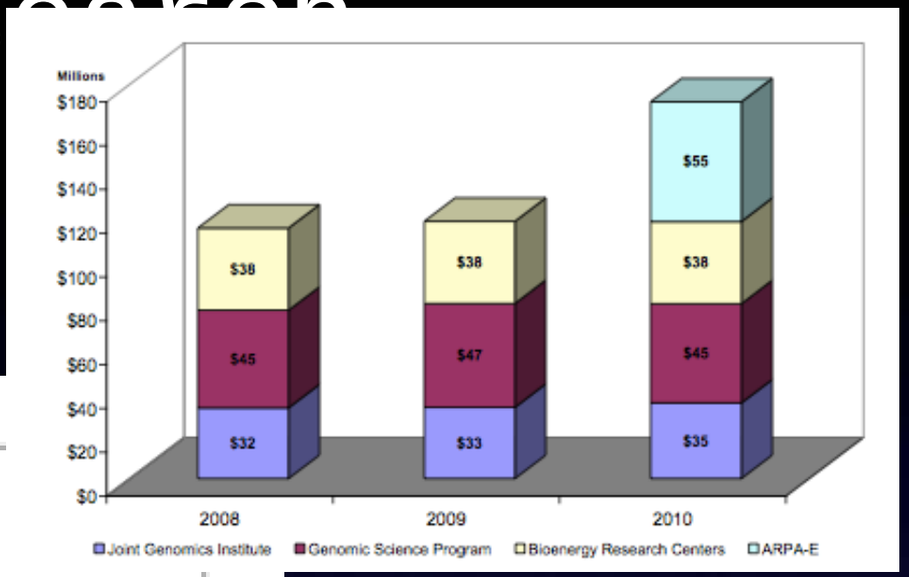
This map shows the locations of companies (C), government laboratories (G), research institutions (R) and universities (U) conducting synthetic biology research and policy centers (P) examining issues surrounding synthetic biology. Available at http://www.synbioproject.org/library/inventories/map/.

1. http://www.researchandmarkets.com/reports/c31390; accessed March 3, 2010.

2. Lux Biosciences Intelligence. 2009. *Synthetic Biology's Commercial Roadmap.* State of the Market Reports. Lux Research. Available at http://www.luxresearchinc.com/info/smr. Accessed March 17, 2010.

Total US and EU Funding for Synthetic Biology Research





DOE Funding

USDA
$2.3
Million
since 2005

From: *Trends in Synthetic Biology Research Funding in the United States and Europe*, June 2010, Synthe

Research Related to Synthetic Biology

ENGINEERING CYANOBACTERIA AS A FACTORY TO PRODUCE METHYLBUTENOL FOR BIOFUEL AND ISOPRENE FOR BIORUBBER

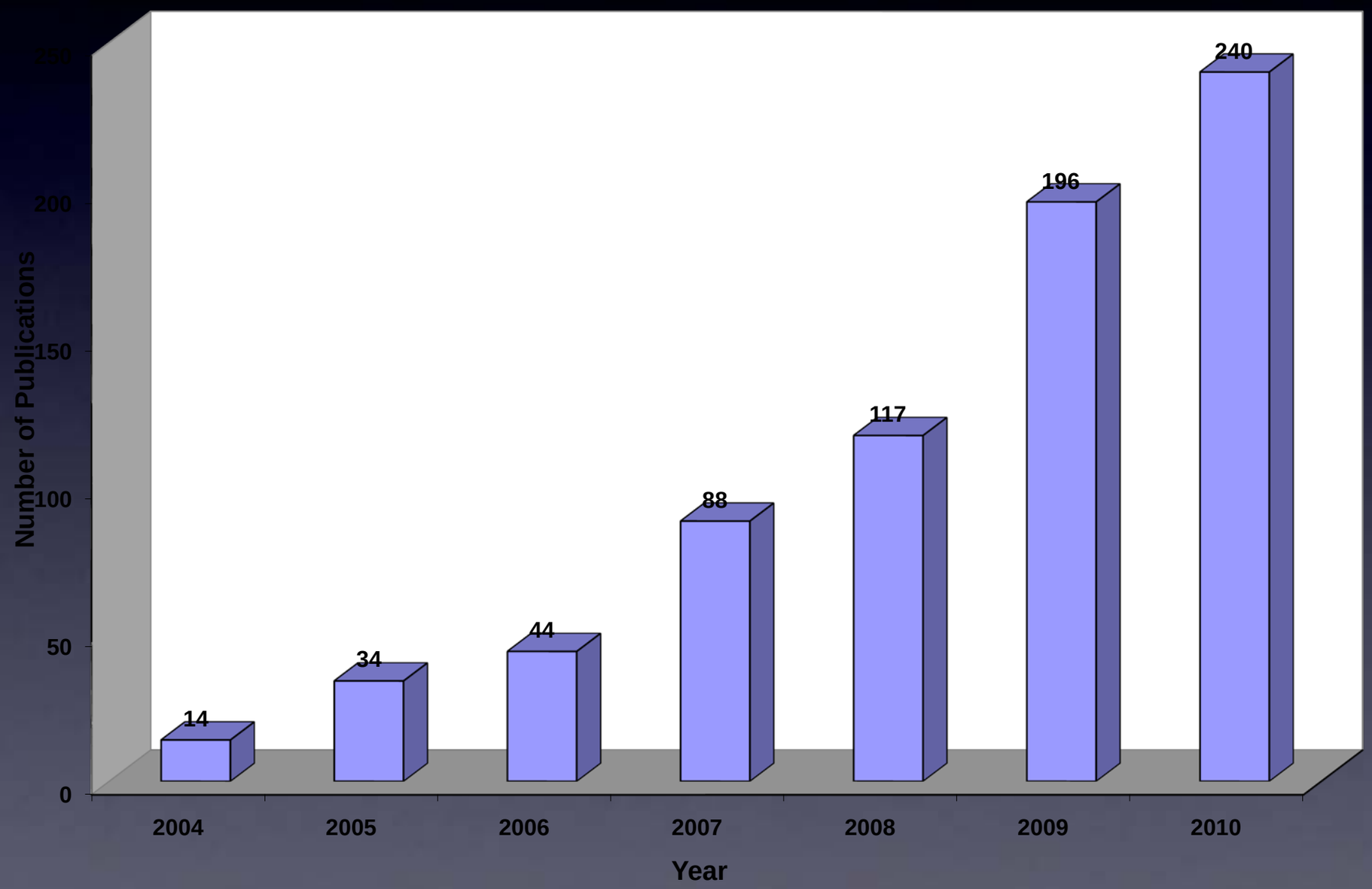
REGULATION OF LIPID METABOLISM IN PLANTS AND ALGAE

LINKAGE ANALYSIS APPROPRIATE FOR COMPARATIVE GENOME ANALYSIS AND TRAIT SELECTION IN SWITCHGRASS

DEVELOPING ASSOCIATION MAPPING IN POLYPLOID PERENNIAL BIOFUEL GRASSES

ETHICAL ISSUES IN AGRICULTURE

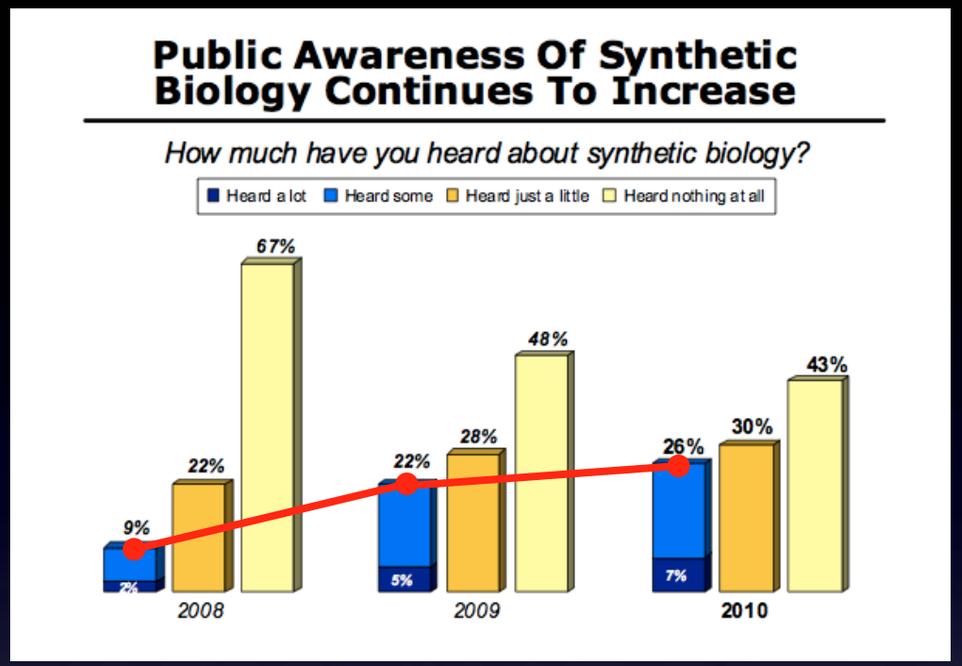
Scientific Publications Listing Synthetic Biology as the Topic



Search on Web of Science, January 6, 2011.

Pubic Awareness of Synthetic Biology?

How Much Have You Heard About Synthetic Biology?



“Having the word 'synthetic' next to the word 'biology' does provoke a reaction in people that can be negative.” Professor Paul Freemont UK Centre for Synthetic Biology

What people think of when they hear the term “synthetic biology”

30% Something man-made, artificial, fake, not natural, not real

12% Has to do with genetic engineering, altering the biological makeup

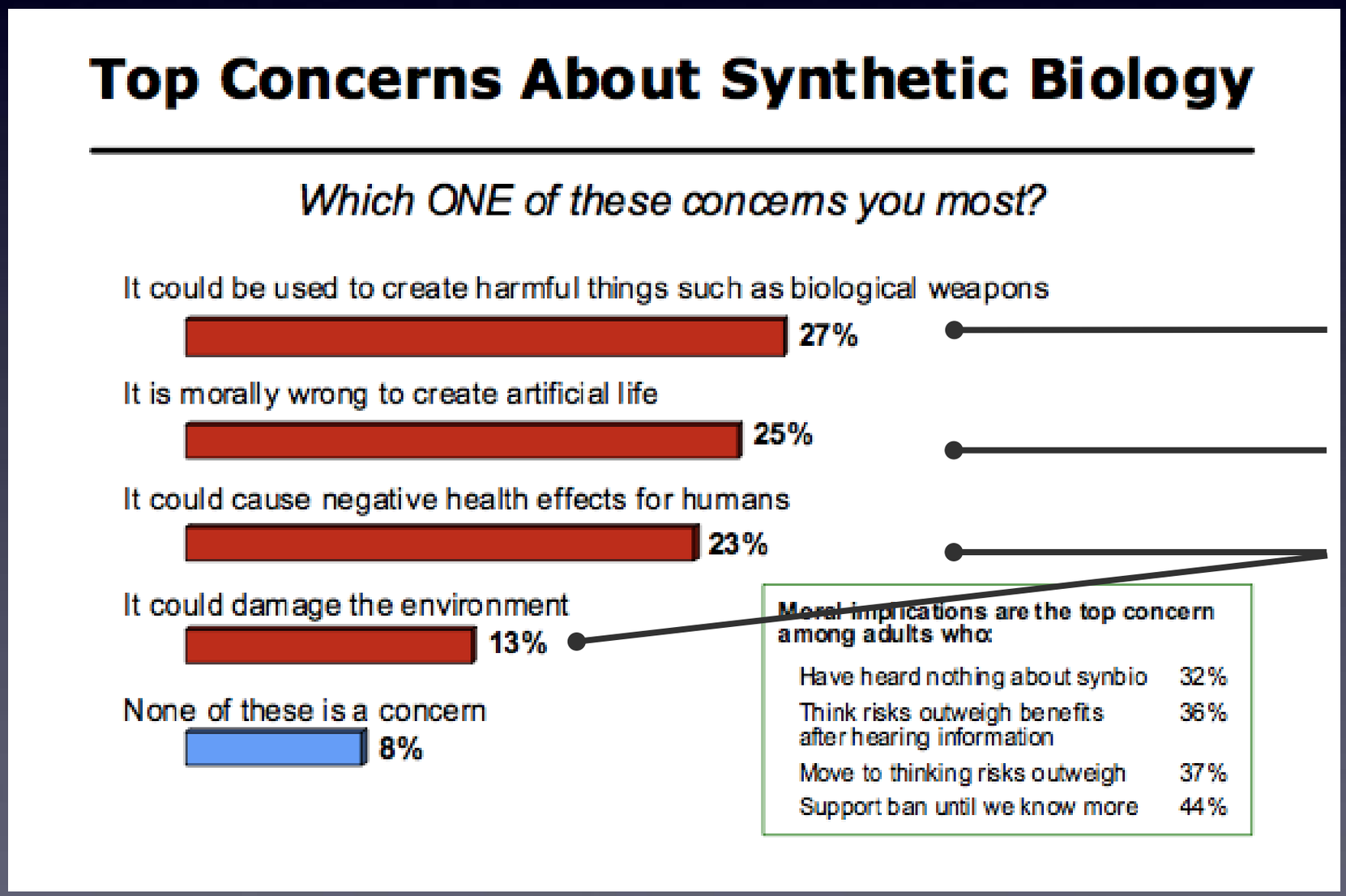
6% Has to do with science, biology, the study of living organisms

6% Cloning

What Do People Worry About?

“All the things that are positive that can be done with it are wonderful, absolutely wonderful. My concern is that maybe by doing this we’ll create something that we can’t control,...”

“....once you start doing this, you open a Pandora ’s box that you’re not going to be able to close. And then we’ll be doing it for things I no longer approve of.”



Biosecurity (2

Ethics (25%)

Biosafety (36%

- Humans (23%)
- Environment (

Moving Forward, with Caution

By Two To One, Public Supports Continued Work In Synbio Over Ban

Which comes closer to your point of view?

Synthetic biology should move forward, but more research must be done to study its possible effects on humans and the environment — 63%

A ban should be placed on synthetic biology research until we better understand its implications and risks — 33%

View By Awareness of Synbio

	Move forward	Ban
Heard a lot	80%	15%
Heard some	76%	20%
Heard a little	66%	29%
Heard nothing	52%	44%

Support for a ban on nanotech in 2005 focus groups was 8%.

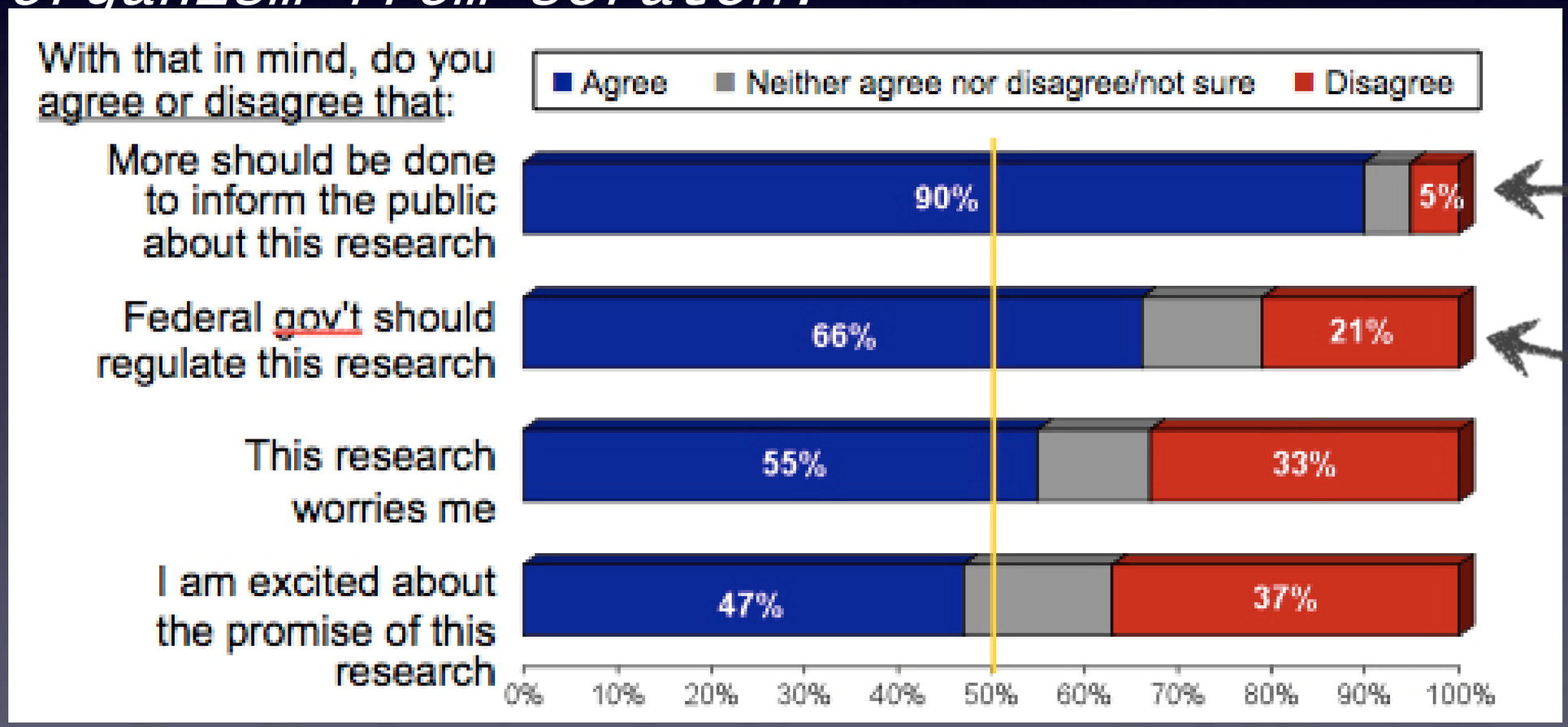
Support For Continued Work Vs Ban, *Among Key Subgroups*

Which comes closer to your point of view?

	Move forward	Ban
All adults	**63%**	**33%**
Men	**72%**	25%
Women	55%	**40%**
High school/less	51%	**45%**
Some college/tech ed	61%	34%
College graduate	**74%**	22%
Whites	**68%**	29%
African Americans	41%	**52%**
Hispanics	53%	**43%**
Income:		
Under $30K	50%	**47%**
$30K to $50K	57%	**38%**
$50K to $75K	**71%**	25%
Over $75K	**80%**	16%
Attend religious services weekly	56%	**39%**
Evangelicals	51%	**43%**

Public Desire for Dialogue & Regulation

"While the issues we have been discussing may seem hypothetical and far into the future, the creation of synthetic life forms may be very close. Recently, researchers announced that within a few months they will be able to create artificial life in the form of a synthetic organism from scratch."



"Without effective public engagement, there will be no synthetic biology in Europe." Nature Magazine, 6/10/2010

Artificial life 'needs regulation'

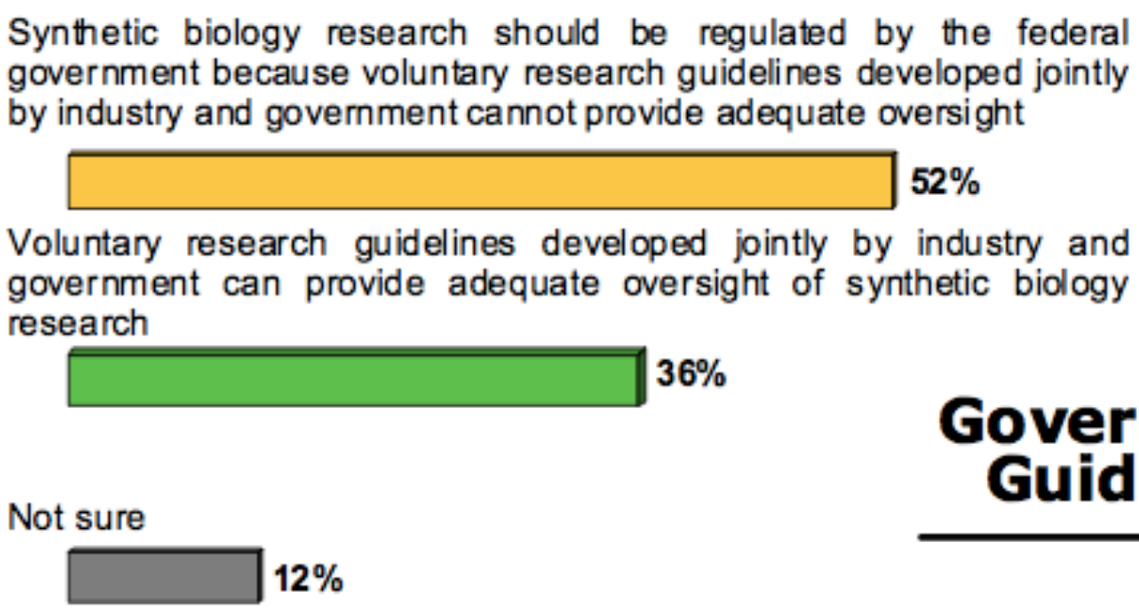
2009 UK Public Survey

From: *Nanotechnology, Synthetic Biology and Public Opinion*, Washington, DC: Synthetic Biology Project

Regulation vs. Voluntary Controls

Majority Wants Government Regulation

Which comes closer to your point of view on regulation of synthetic biology research?

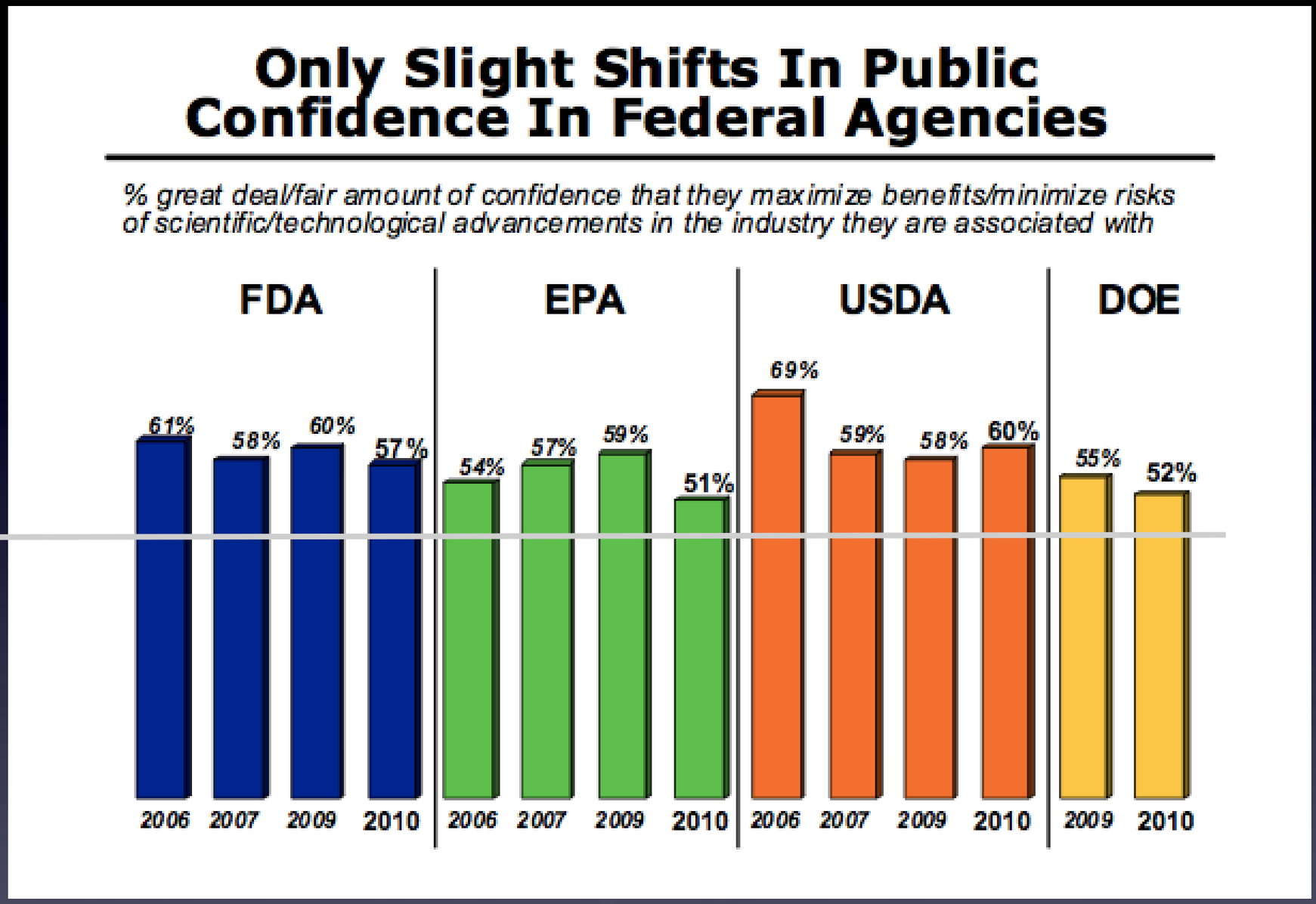


Government Regulation Vs Voluntary Guidelines, *Among Key Subgroups*

Which comes closer to your point of view on regulation of synthetic biology research?

	Need Gov't Reg.	Voluntary Guidelines
All Adults	**52%**	**36%**
Men	49%	40%
Women	54%	32%
High school/less ed	56%	31%
Some college	53%	33%
College graduates	49%	41%
Whites	47%	40%
African Americans	63%	25%
Hispanics	59%	26%
Income:		
Under $30K	62%	25%
$30K - $50K	54%	34%
$50K - $75K	48%	38%
Over $75K	49%	43%
Democrats	64%	28%
Independents	49%	37%
Republicans	42%	44%

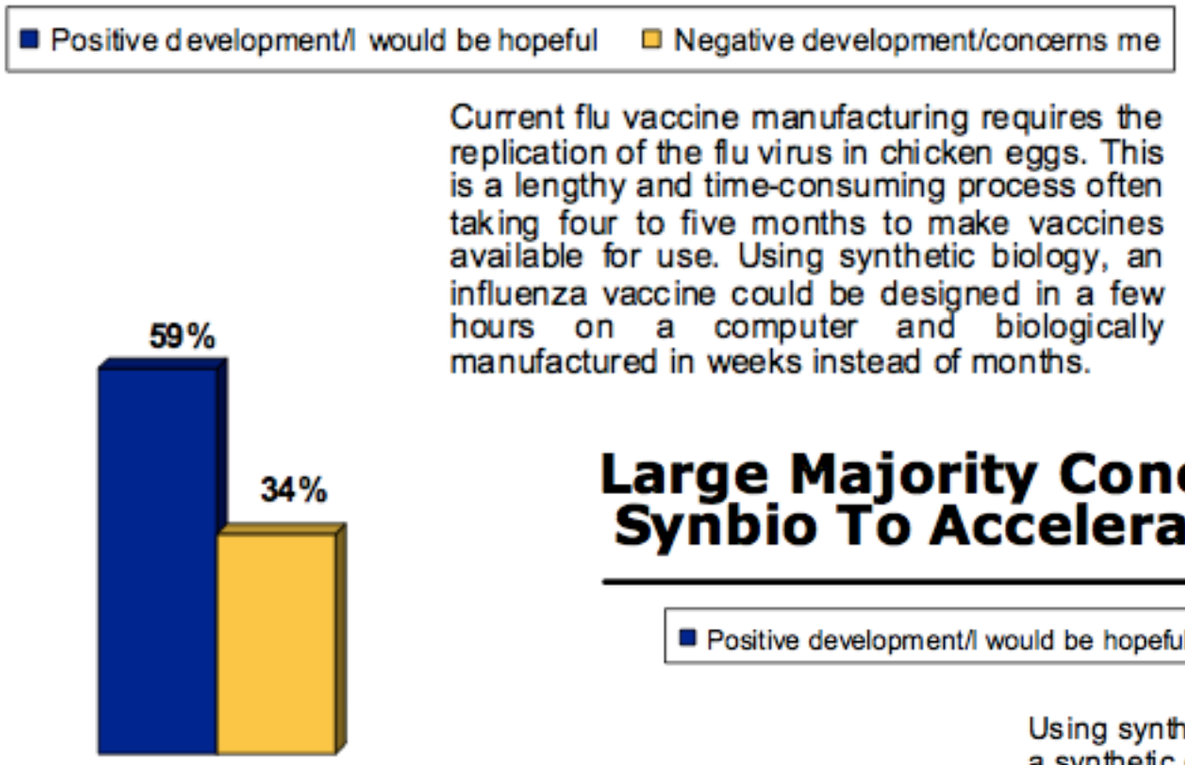
Trust: .gov Still Beats .com



Only **44%** have a great deal or a fair amount of confidence in businesses and companies to maximize benefits and minimize risks associated with scientific and technological advancements. The proportion who say they have very little confidence (**25%**) is at the highest level measured since the first poll Hart Research Associates conducted for The Wilson Center in 2006.

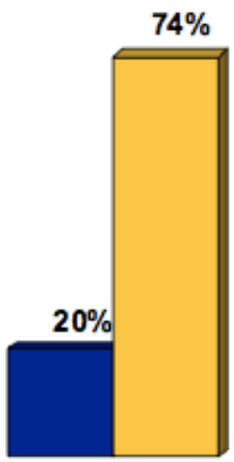
Applications Matter

Majority See Developing Flu Vaccine With Synbio As Positive Development



Current flu vaccine manufacturing requires the replication of the flu virus in chicken eggs. This is a lengthy and time-consuming process often taking four to five months to make vaccines available for use. Using synthetic biology, an influenza vaccine could be designed in a few hours on a computer and biologically manufactured in weeks instead of months.

Large Majority Concerned About Using Synbio To Accelerate Animals Growth



Using synthetic biology, researchers could insert a synthetic chromosome designed on a computer into cows or pigs that would allow the animals to mature in four months instead of eight months. Other than the acceleration of growth, the animals would look and act exactly like regular pigs and cows, but it would mean that farmers could produce meat for consumers more quickly

Only 33% of those who feel positive about the flu vaccine application also feel positive about using synbio to accelerate animal growth.

There are NO groups among whom a majority feel positive about this application.

Synthetic Biology: The 3 Voting Blocks

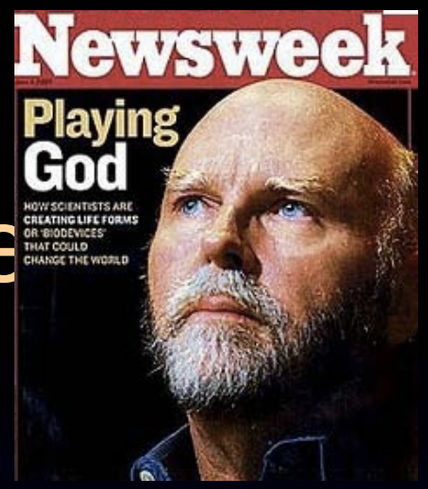
I Hate It

Convince Me

I Love It

Recent Developments

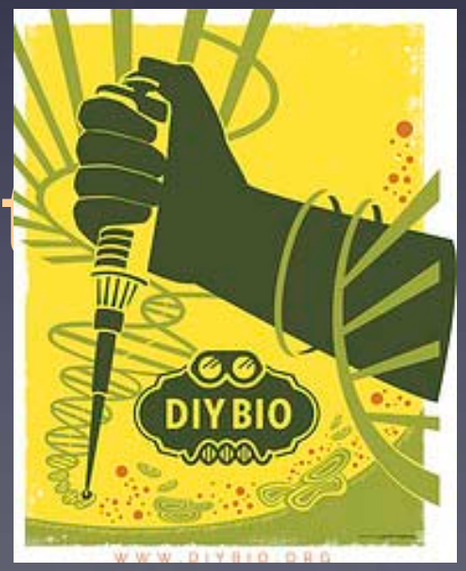
J.C. Venter Institute Announce



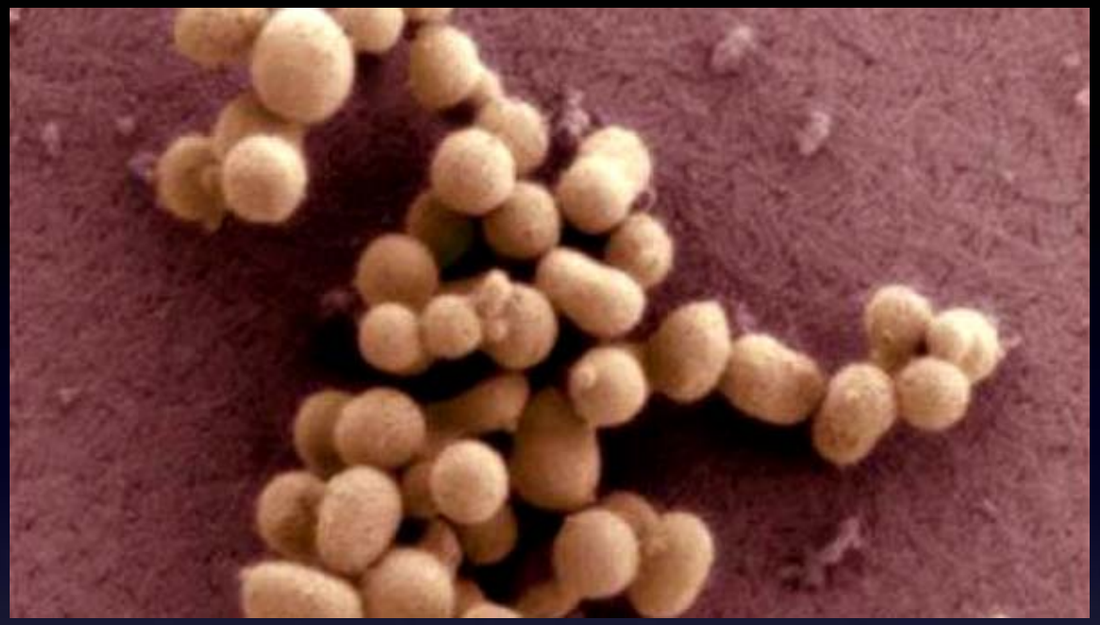
ident's Bioethics Commission (December)

The President asked the Commission to develop ``recommendations about **any actions** the Federal government should take to ensure that America reaps the benefits of this developing field of science while identifying appropriate ethical boundaries and minimizing identified risks.'

DIY-Bio Movement



s this a Big Deal?



Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome

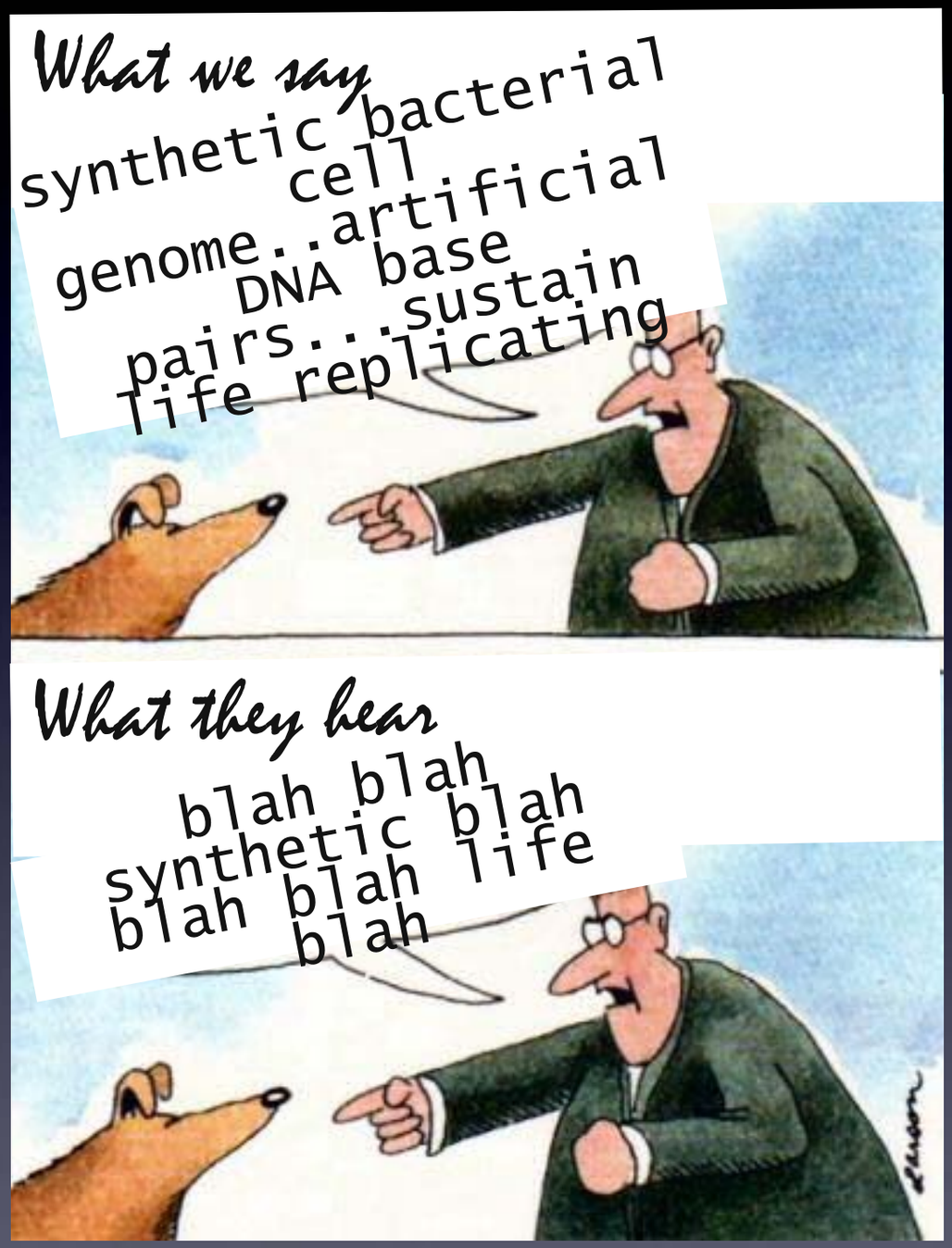
“The ability to design and create new forms of life marks a turning-point in the history of our species and our planet.”

Freeman Dyson

“Craig has somewhat overplayed the importance of this.”

David Baltimore

What the Public Heard



Cartoon Adapted from Far Side

Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome

Daniel G. Gibson,[1] John I. Glass,[1] Carole Lartigue,[1] Vladimir N. Noskov,[1] Ray-Yuan Chuang,[1] Mikkel A. Algire,[1] Gwynedd A. Benders,[2] Michael G. Montague,[1] Li Ma,[1] Monzia M. Moodie,[1] Chuck Merryman,[1] Sanjay Vashee,[1] Radha Krishnakumar,[1] Nacyra Assad-Garcia,[1] Cynthia Andrews-Pfannkoch,[1] Evgeniya A. Denisova,[1] Lei Young,[1] Zhi-Qing Qi,[1] Thomas H. Segall-Shapiro,[1] Christopher H. Calvey,[1] Prashanth P. Parmar,[1] Clyde A. Hutchison, III,[2] Hamilton O. Smith,[2] J. Craig Venter[1,2,*]

Published Online May 20, 2010
Science DOI: 10.1126/science.1190719

U.S. Press Headlines
May 20-25, 2010
Type size indicates relative frequency of word use

ident's Bioethics Commission (December)

Responsible stewardship calls for *prudent vigilance*, establishing processes for assessing likely benefits along with safety and security risks both before and after projects are undertaken.

Recommendation 5: Risk Assessment Review and Field Release Gap Analysis

Recommendation 6: Monitoring, Containment, and C

Recommendation 7: Risk Assessment Prior to Field Release

Recommendation 12: Periodic Assessment of Security & Safety Risks

Recommendation 13: Oversight Controls

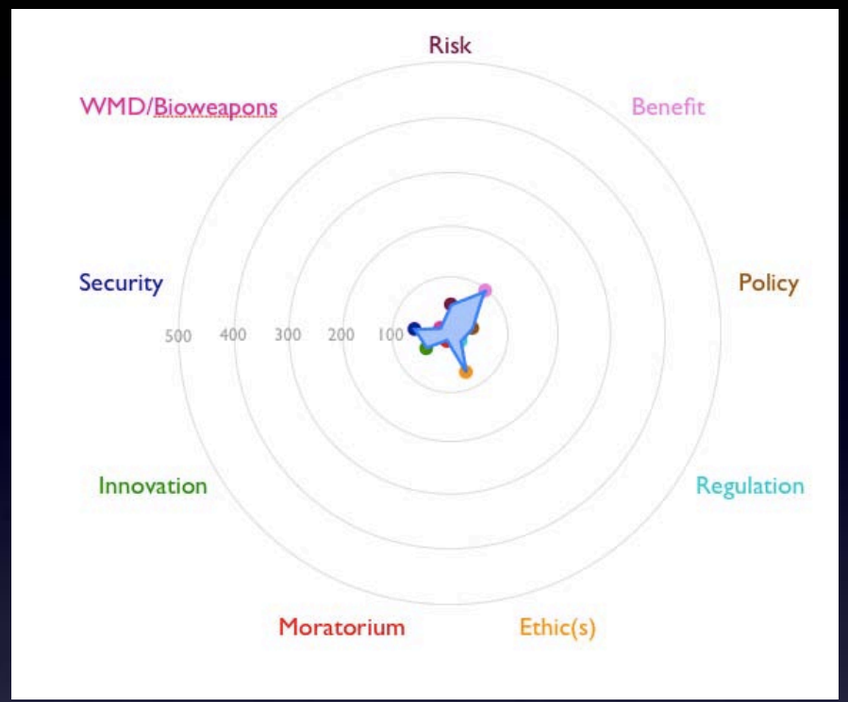
Recommendation 16: Public Education

Recommendation 18: Risks and

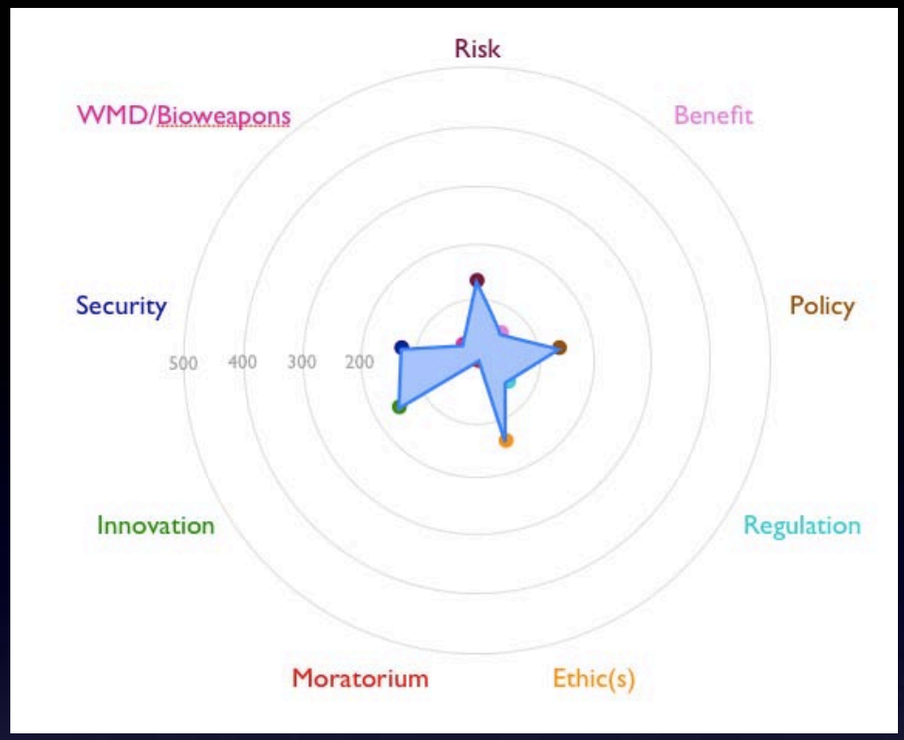
Synthetic Biology Issues

Press & Wire Media Coverage

2008



2009



2010

Rise of the Do-It-Yourself Biology Movement

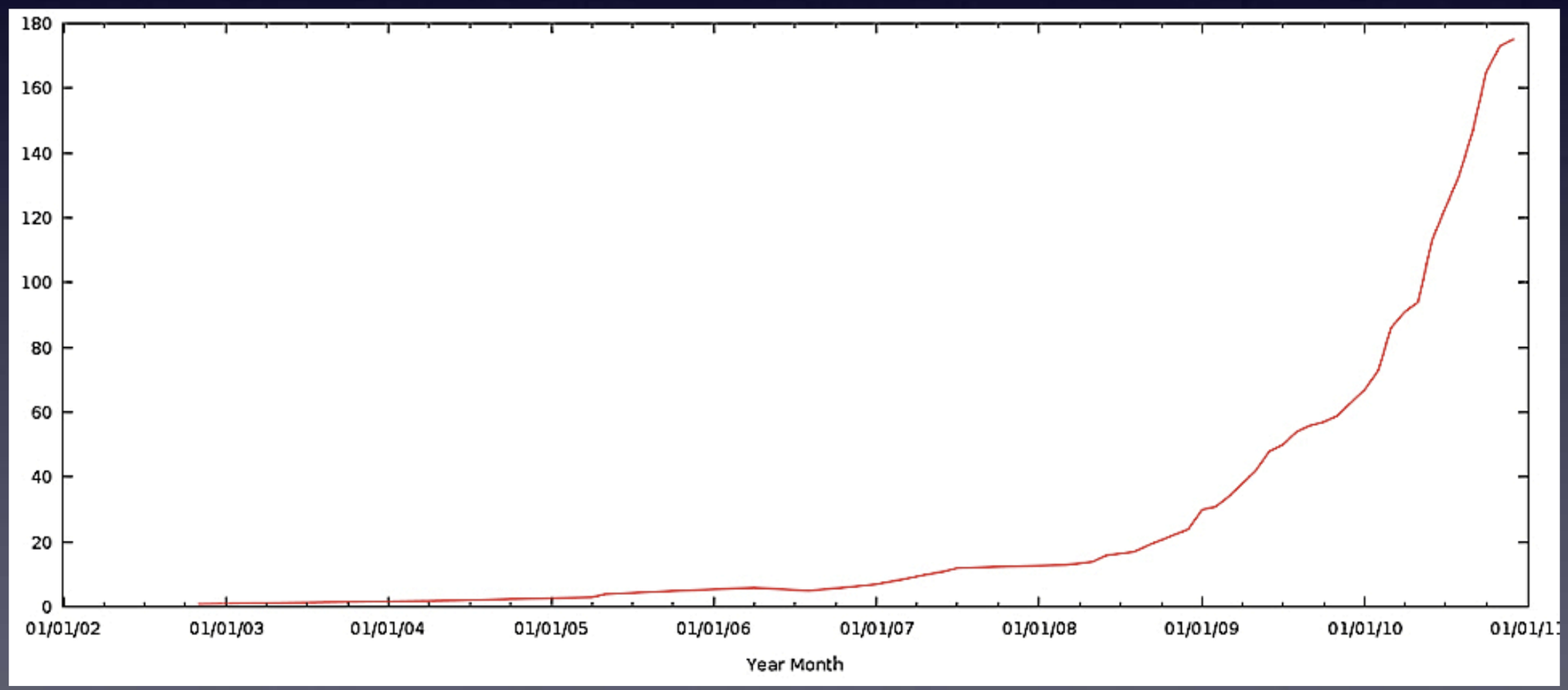
Garage biotech: Life hackers

Amateur hobbyists are creating home-brew molecular-biology labs, but can they ferment a revolution?

'Biohackers' Push DIY Science in the Basement

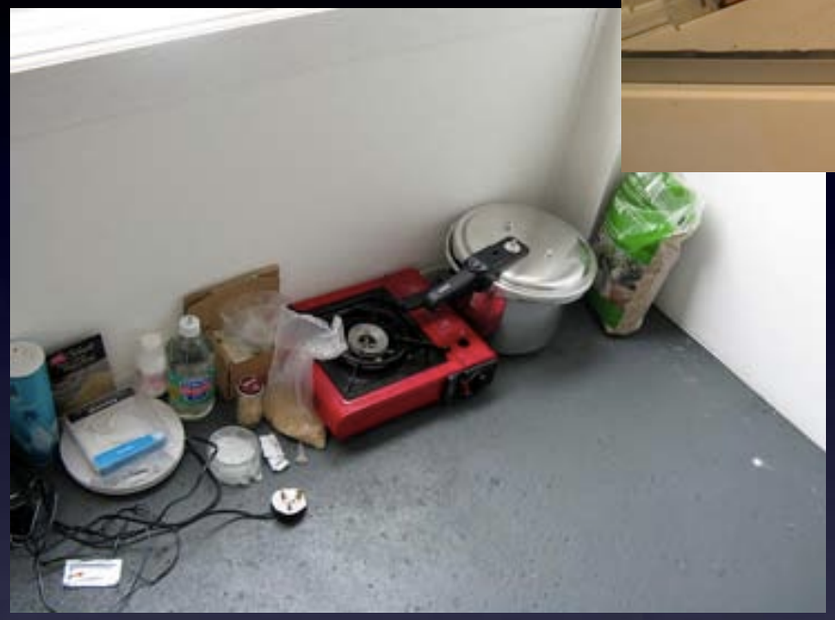
MOVEMENT AIMS TO CAPITALIZE ON AMERICAN PASSION FOR INVENTION

Garage Biology...What's Cookin in Your Neighborhood?



DIY Bio Articles

Home and Garage Bio Labs



Hundreds of hackerspaces currently exist in the United States and throughout the world, see http://hackerspaces.org/wiki/List_of_Hacker_Spaces

Emergence of Community Biolabs

GENSPACE

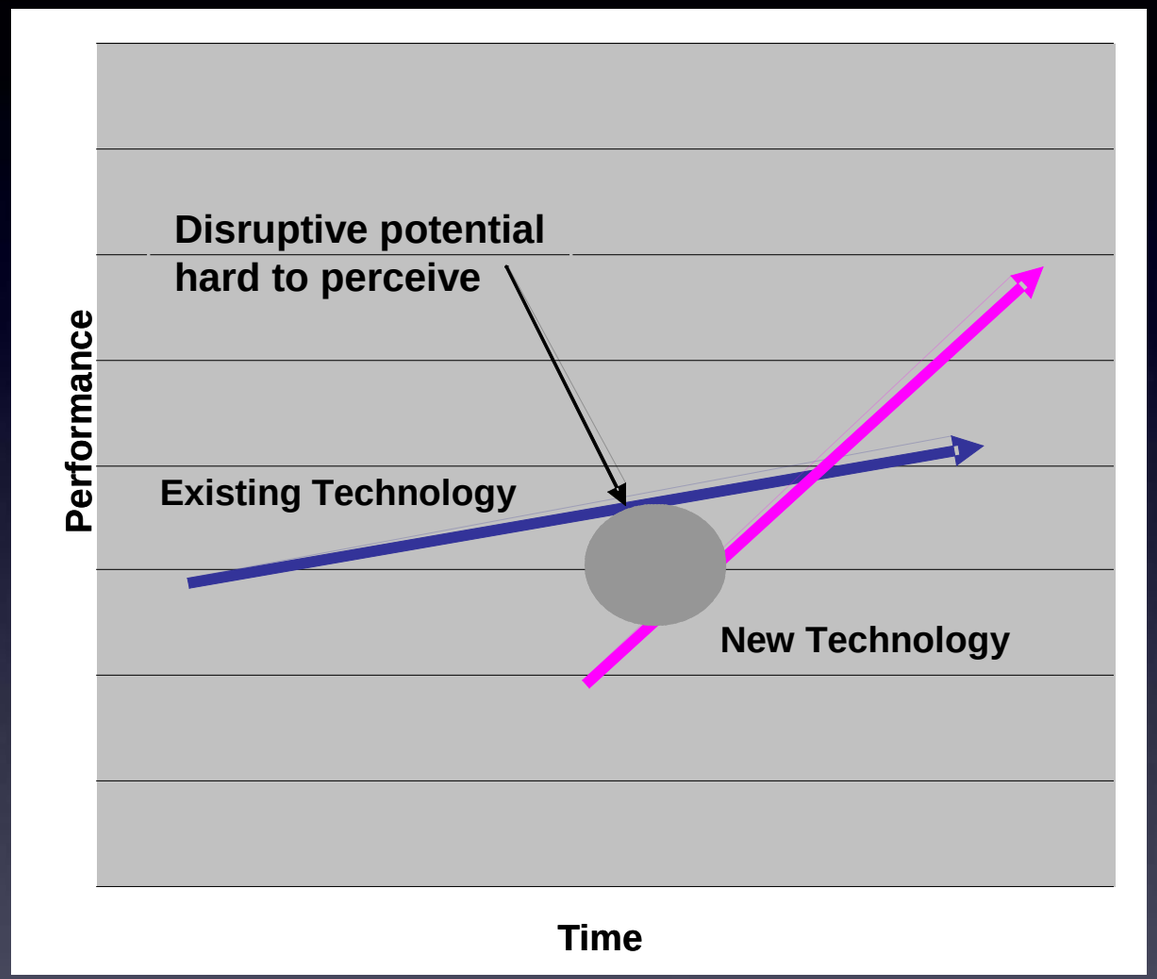
New York City's Community Lab

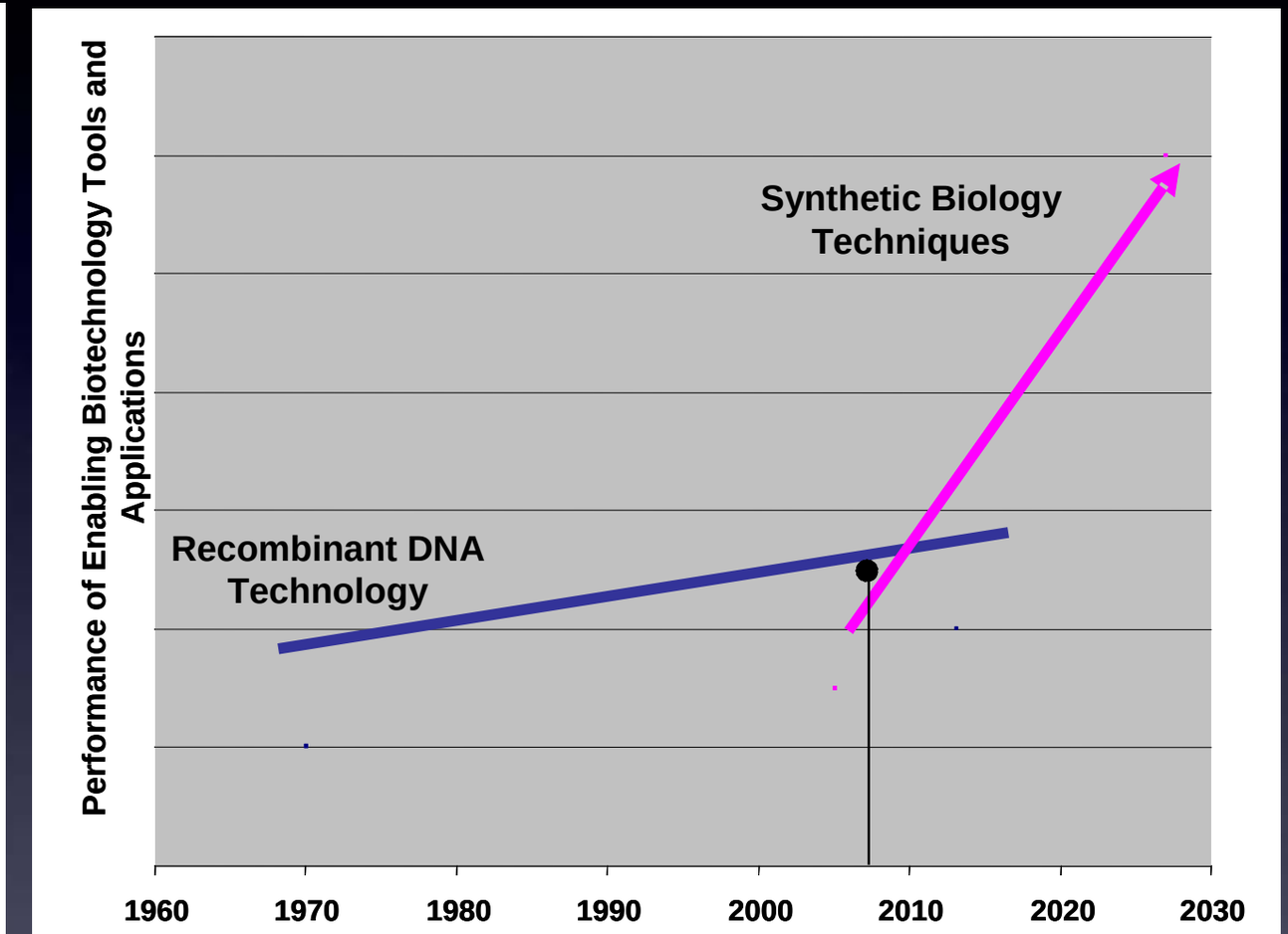
Remember when science was fun?

At Genspace it still is.

Genspace is a nonprofit organization dedicated to promoting education in molecular biology for both children and adults. We work inside and outside of traditional settings, providing a safe, supportive environment for training and mentoring in biotechnology.

Is this a Disruptive Technology?





Adapted from: Christensen, Clayton 1997. *The Innovator's Dilemma*, NY: Harper Business.

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www.synbioproject.org