Synthetic Life:
Our Hybrid Future

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Biomedical Engineering

Purdue University

Share your thoughts and ideas…

text M5672 + your message

765-560-4177

DAWN OR DOOM

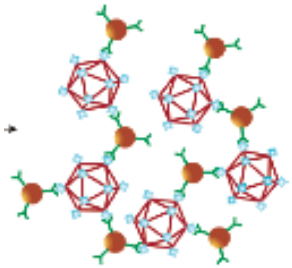
THE NEW TECHNOLOGY EXPLOSION

What is Synthetic Life?

What is Hybrid Technology?

SYNTHETIC LIFE

?

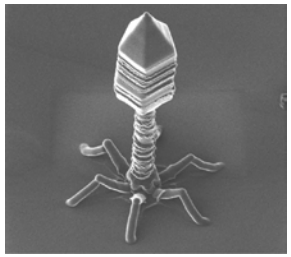


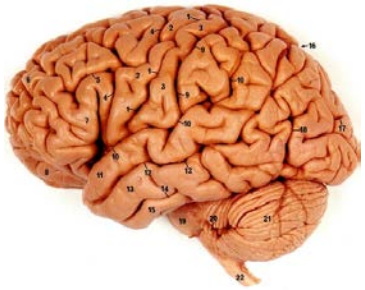
ROSI ET AL 2005

SYNTHETIC

NATURAL

SCALE / COMPLEXITY





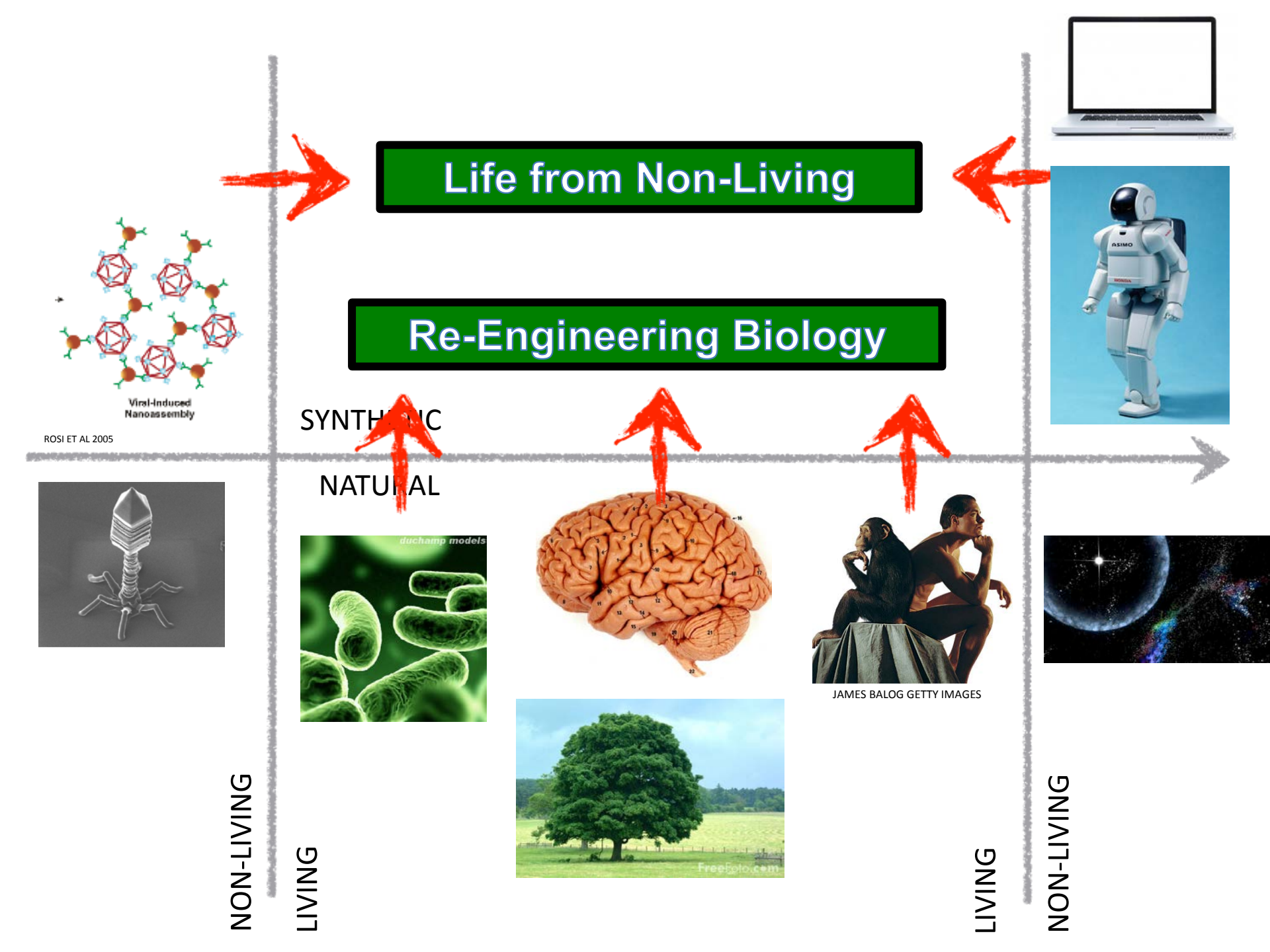
JAMES BALOG GETTY IMAGES

NON-LIVING

LIVING

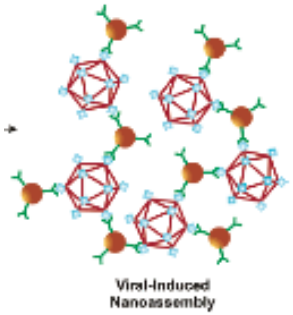
LIVING

NON-LIVING


Life from Non-Living
Re-Engineering Biology
Viral-Induced Nanoassembly
ROSI ET AL 2005
SYNTHETIC
NATURAL
duchamp models
JAMES BALOG GETTY IMAGES
NON-LIVING
LIVING
LIVING
NON-LIVING

BioNanotechnology

Artificial Intelligence



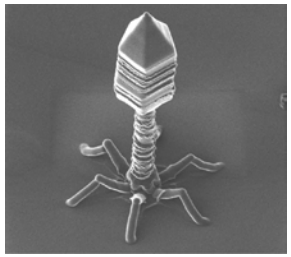
ROSI ET AL 2005

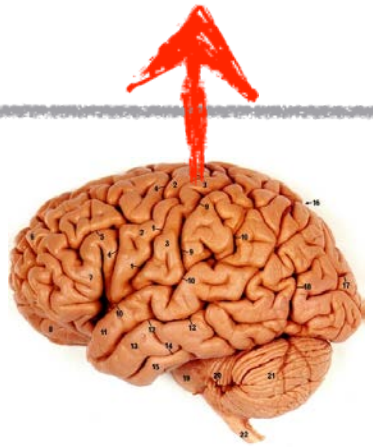
Synthetic Biology

Tissue Engineering
Neuro Engineering

SYNTHETIC

NATURAL





JAMES BALOG GETTY IMAGES

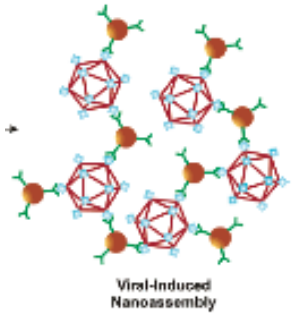
NON-LIVING

LIVING

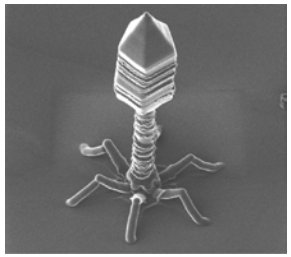
LIVING

NON-LIVING

Our Hybrid Future

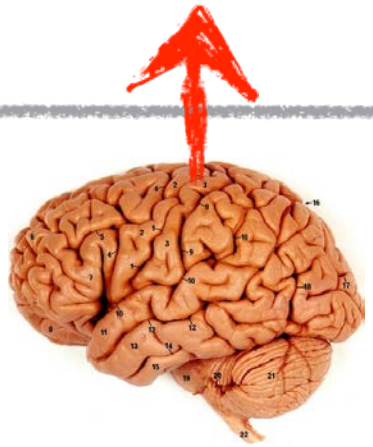


ROSI ET AL 2005



SYNTHETIC

NATURAL



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NON-LIVING

LIVING

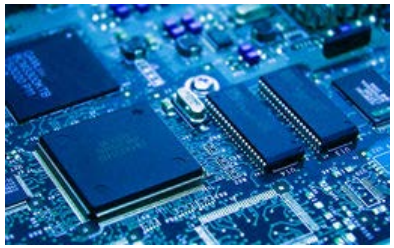
LIVING

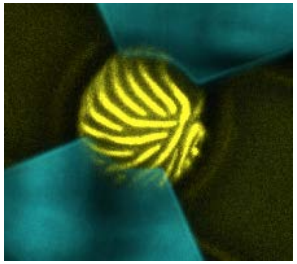
NON-LIVING

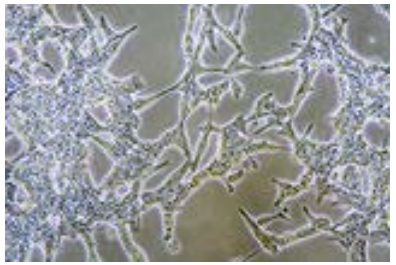
Engineered

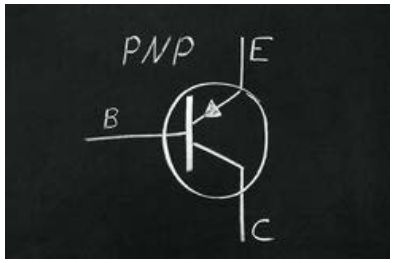
Hybrid

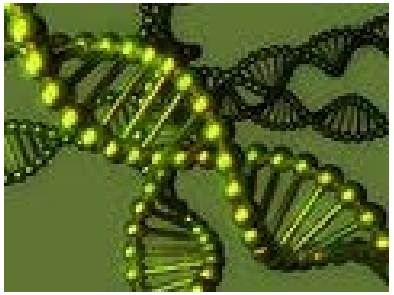
Biological











Brophy & Voigt, 2014

Si

Pt

Au

Cu

Hybrid Chemistry

C

O

P

N

H

Why Hybrid? Why do we need the Bio?

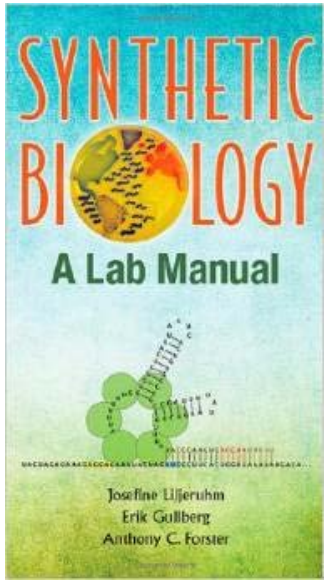
"**Biological engineering** **is poised to outdo all previous engineering fields**"

(1) ability to miniaturize in 3 and 4 dimensions

(2) inherited billions of years of evolutionary innovation and testing an unparalleled list of parts, systems and applications

(3) can combine (1) and (2) to produce accelerated evolution

Moore's Law → ~ 1.5 fold per year
Rate of biotechnology → ~ 8 fold per year



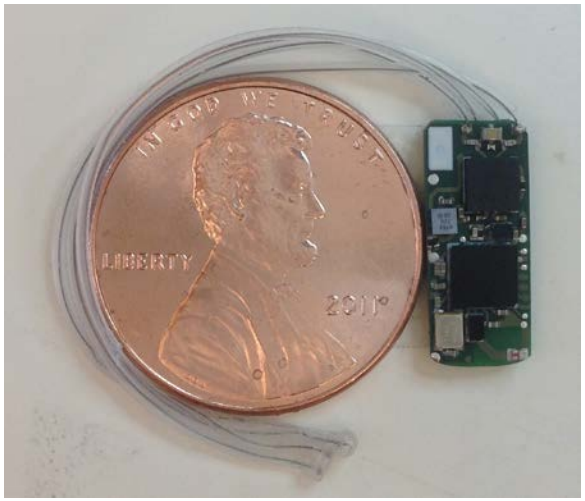
George Church, Harvard
Foreword to Synthetic Biology: A Lab Manual

NeuroEngineering → Neural Implants

Science Fiction

http://discovermagazine.com/2013/march/1-matrix-learning

Science



Wireless neural implant
Records, Stimulates
Up to 8 in one patient

Pedro Irazoqui, Purdue University
Center for Implantable Devices

NeuroEngineering → Neural Implants

Why?

Because ….
~1% of the world has epilepsy
&
30% - 40% of patients have drug resistant seizures




http://www.cureepilepsy.org/

CURE
Citizens United for Research in
EPILEPSY

NeuroEngineering → the Brain Computer Interface

Science Fiction

AMPed war exoskeleton

James Cameron movie, Avatar

Science

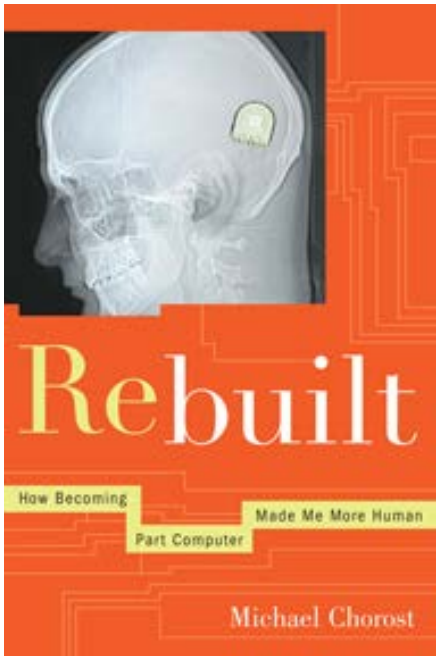
Mind-controlled exoskeleton

http://www.cbsnews.com

NeuroEngineering → the Brain Computer Interface

Why?

To restore the ability to experience and engage with the outside world to those who have lost that ability.



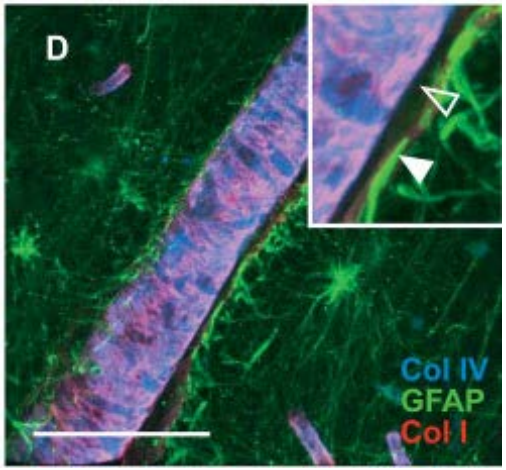
http://michaelchorost.com/books/

Tissue Engineering → Organs in the Lab

Science Fiction

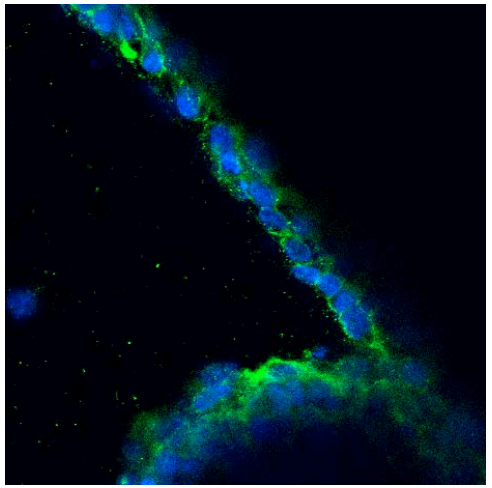
Science

Real
Human Brain



Gritsenko et al 2012

Engineered
Human Brain



Rickus Lab

Watching tumor cells from a human patient migrate along a pseudo blood vessel in an engineered brain.

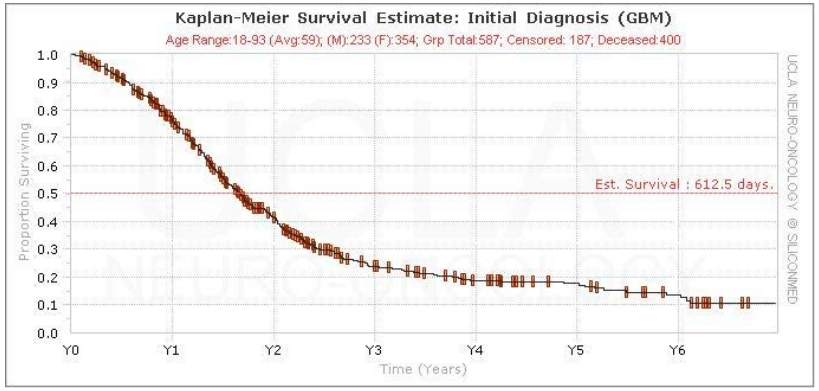
Tissue Engineering → Organs in the Lab

Why?

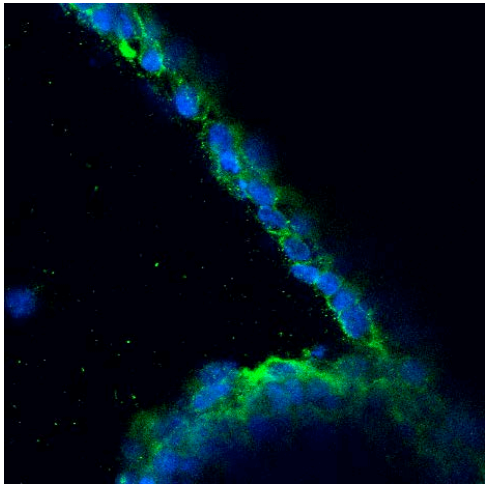
Because …

the median survival after diagnosis with glioblastoma is 15 – 18 months

current cell and animal models do not predict therapy outcomes in humans



http://www.neurooncology.ucla.edu/Performance/GlioblastomaMultiforme.aspx



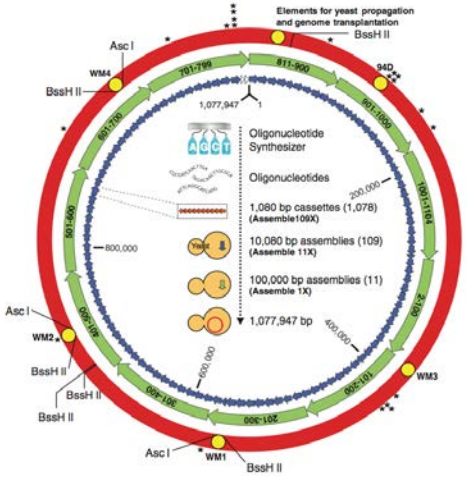
Synthetic Biology → Writing Genomes

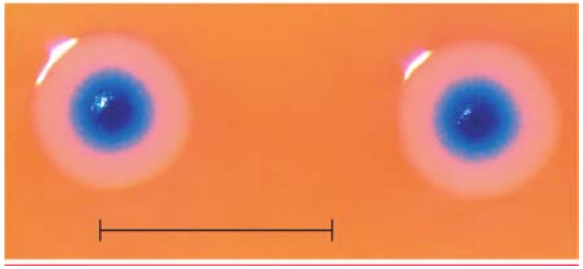
Science Fiction

https://thehungergames2012.wordpress.com

Science

2010 – the first genome transplant of a chemically synthesized genome





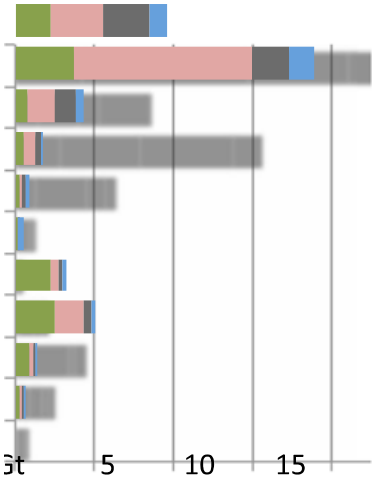
Gibson et al. Science 329, 52 (2010)

Synthetic Biology → Writing Genomes

Why?

Because …

Human global extraction of earth's raw materials is 70 billion metric tons / year



The Materials Footprint of Nations. PNAS. Wiedmann et al 2013

http://earthobservatory.nasa.gov

iGEM

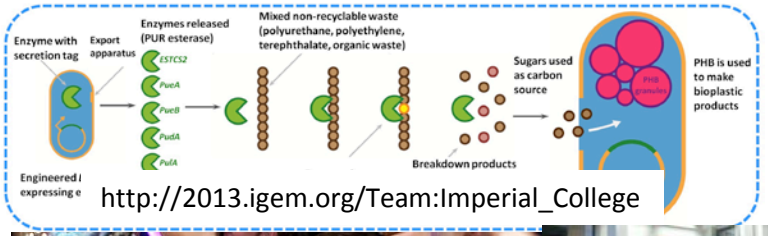
http://igem.org

40 HEALTH AND MEDICINE
36 ENVIRONMENT
31 NON-SPECIFIED
29 FOUNDATIONAL ADVANCE
25 FOOD AND ENERGY
24 NEW APPLICATION
13 MANUFACTURING
12 INFORMATION PROCESSING
8 SOFTWARE
4 ENTREPRENEURSHIP

215 TEAMS

Module 1: Resource-full Waste

From trash to bioplastic



http://2013.igem.org/Team:Imperial_College

Ivy Tech

http://2013.igem.org/Team:Purdue

What Defines These Boundaries?

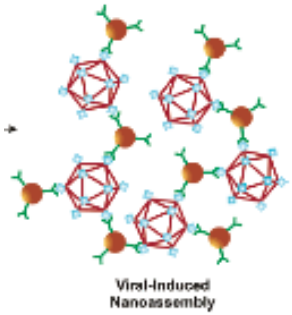
What is Life?

What is Human?

What is Synthetic?

Is it important to know when we've crossed?

Does Synthetic = Unnatural?



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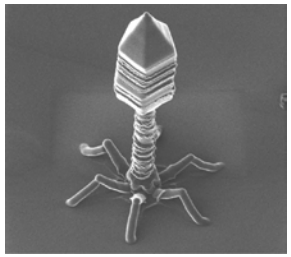
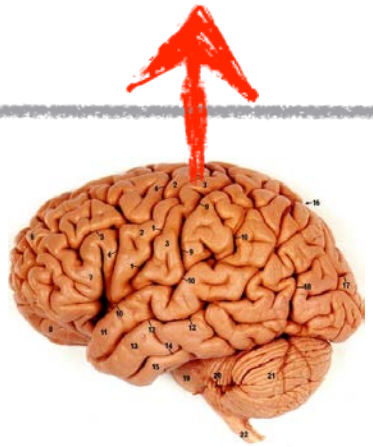
SYNTHETIC

NATURAL





JAMES BALOG GETTY IMAGES

NON-LIVING

LIVING

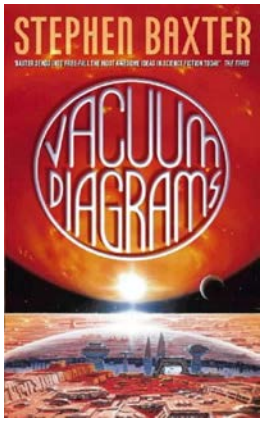
LIVING

NON-LIVING

A Working Definition of Life?

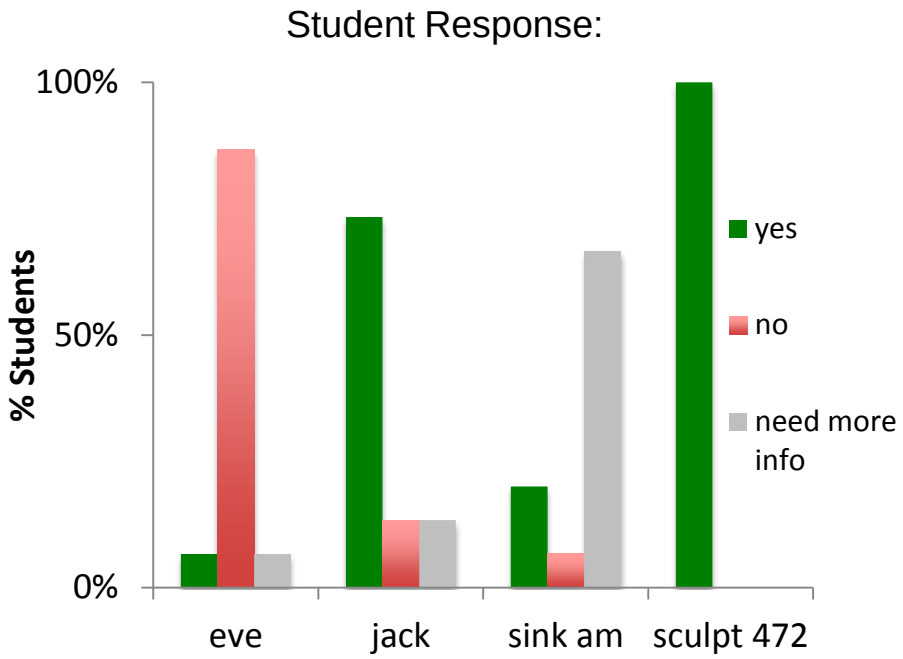
Function	• Metabolize, Evolve, Replicate
Thermodynamics	• Decreases the entropy of its own system
Control	• Respond to surroundings • Strive for conservation
Cognitive	• Goal-oriented • Self-aware
Beyond Current Understanding	• Human intellect cannot fathom • Evaluated on case by case basis • Life can come in many forms

A Working Definition of Life?



Based on your working definition,
is the character living?

Eve	Representation/simulation of Jack's dead human wife who learns, has all old & makes new memories
Jack	Man whose body has been replaced with alien form Can exist with Eve in virtual reality
Sink Ambassador	Alien whose natural form is like Jack's new form
Sculptor 472	Alien sentient creature of ice, helium, hydrogen; on different time scale

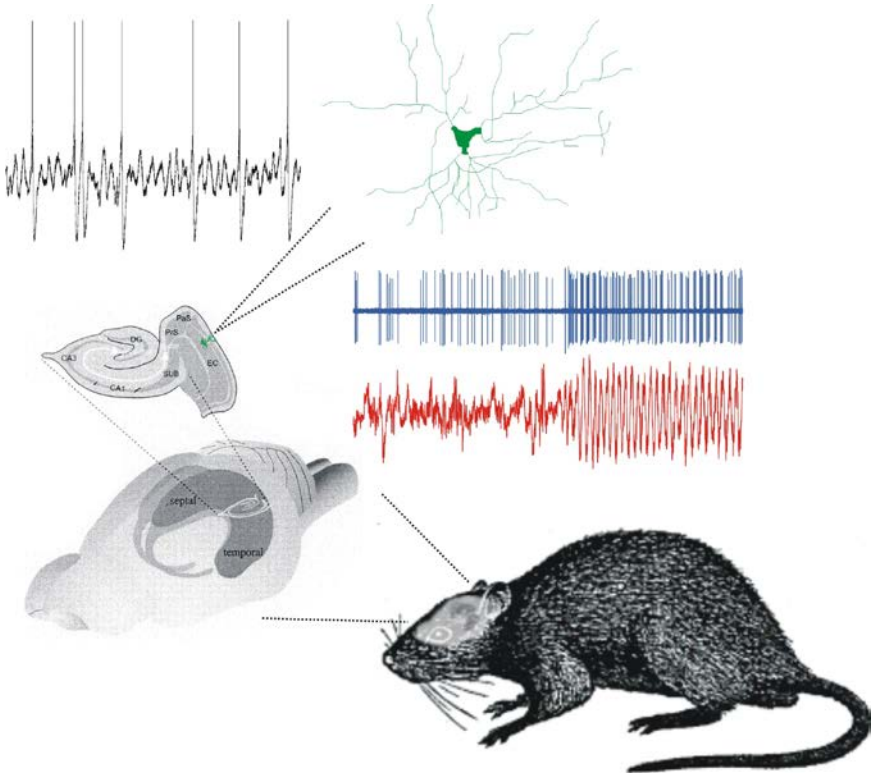


Lessons: Substrate - was less relevant to the students
Perspective - 1st person perspective affected opinion

Synthetic Consciousness?

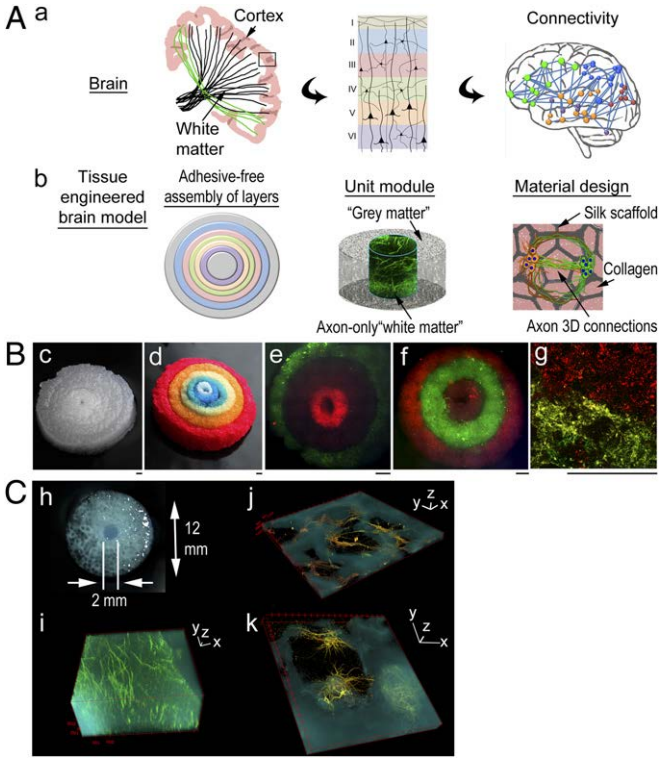
Could I assemble a neural construct (from circuits or cells) that attains consciousness?
How would I know?
I can't have the 1st person perspective given to me in Vacuum Diagrams.

Reduction – Brain Slice
When is consciousness lost?



http://www.psych.ualberta.ca/~cdickson/facilities.html

Construction – Engineered Cortex
When does consciousness emerge?



http://www.pnas.org/content/early/2014/08/06/1324214111

What makes us human?

hardware: Is humanity in the biological substrate?

software: Is humanity in the input output functions and interaction with the outside world and other people?

When are we modified to a point that we are synthetic?

Synthetic manipulation of higher function?

Memory Emotion Attention

What then about

Identity Free Will Responsibility

In the Context of AI and Superintelligence

Beyond Brain Machine Interface Workshop: From Senses to Cognition

(Sponsored by Army Research Office and IEEE EMBS)

Brain-machine interfaces (BMI) have inspired popular culture and captured the imaginations of scientists and non-scientists alike. This relatively new field emerged in the 90's with the primary aim of replacing or augmenting communication channels in the severely paralyzed. Since then, developments in neuroscience, neural interface technology, and algorithms have led to rapid progress in diverse areas such as neural, speech and visual prosthetics to name a few. As with the field of neuroprosthetics, which has reached critical mass, it seems inevitable that the use of brain-controlled devices will extend beyond clinical need into cognitive and physical augmentation of healthy individuals.

Spring 2010

Might the path to super-intelligence be to make humans part computer?

Human-Computer Hybrids?

Common Risks / Concerns

- Biosecurity: Bioterrorism & War
- Biosafety: Bioerrorism
  - Modified or Synthetic Organisms will Escape
  - AI will escape and out-think & destroy us
  - Accidental exposure
- Environmental
  - Biology is unpredictable – Wreak Havoc
  - Further separates humans from nature
- Its Unnatural
  - Abominations

Technology & Destruction

- With human progress → violence has decreased
  we are less likely to die at the hands of another human

  http://www.ted.com/talks/steven_pinker_on_the_myth_of_violence

- "increasing lethality of our hatred"
  a few are more capable of killing many

  http://www.ted.com/talks/robert_wright_on_optimism

- AI, brain-computer interface, synthetic biology
  give us new ways to kill each other and ourselves

- Cannot forget natural possibilities for extinction
  technology may be our best hope to fight infectious disease
  1918 Spanish Influenza infected 1/5 of the world's population
  doing nothing is a choice that has risk

Myth of Technological Determinism

Technology is …

- primary governing force for societal change
- shapes a society's values, social structure, and history.

Social progress …

- is driven by technological innovation
- therefore follows an "inevitable" course.

The National Academies. 2010.

http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-569LNP?OpenDocument

Myth of Technological Determinism

- Implicitly embedded collective memory and historical teachings
  - Eli Whitney → Cotton Gin → Slavery Grew → Civil War
  - Gutenberg → Printing Press → Bibles in Hands → Fueled Reformation
  - Jenna Rickus → artificial brain tissue → cure brain tumors → global peace

- "Technology suddenly appears and important things happen"
  - Genius inventor
  - "consequences rather than the genesis of the invention"*

- Problem
  - Decouples average citizen from technology development
  - Ignores the societal forces that drove the technology
  - Leaves us feeling outcomes are inevitable

* "Does Technology Drive History? The Dilemma of Technological Determinism?" Smith & Marx. 1994. MIT Press

The National Academies. 2010. http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-569LNP?OpenDocument

ACTION: Improve Technical Literacy of Citizens

http://www.nae.edu/nae/techlithome.nsf/weblinks/KGRG-569LNP?OpenDocument

ACTION: Work on the Hatred, Keep Technology Moving Forward

http://www.ted.com/talks/robert_wright_on_optimism

ACTION: Engineers need to understand societal forces driving technology

Does Synthetic = “Unnatural”?

People feel strongly but cannot always articulate why

Do you view humans as ☐ equal member, part of “nature”?
☐ unique, dominant over, external to “nature”?

Extreme 1

Technology = Human Evolutionary Advantage.
What we have evolved to do to survive.

- All synthetic life
- ∴ technology is natural.

http://howardbloom.net

Extreme 2

We are arrogant to think we have the right to engineer life.

- All synthetic life
- ∴ technology is unnatural

Religious, Scientific, Personal Backgrounds inform this world view
but not science versus religion
Many gradations between the extremes

Many Directions for Conversation and Study
that I did not Cover

Cognitive Illusions

influence Risk Assessment of Technologies and Decision Making

Ethical Frameworks

testing sufficiency of our bioethics frameworks (e.g. Principlism) for synthetic life and hybrid technologies.

Global Oversight of Technology

Laws and regulations are federal but Impact and reality is global

Moral Status

modified and synthetic organisms and humans

Thank You!

Continue the Conversation!

text M5672 + your message

765-560-4177

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THE NEW TECHNOLOGY EXPLOSION