# Introduction to Synthetic Biology

Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5

## Foundations for Synthetic Biology

Vincent Rouilly
Bioengineering Department
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# Standard for Physical DNA Composition

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Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5

# Standards
# for Functional Composition

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Imperial College London

# Introduction to Synthetic Biology

Topic 1 | Topic 2 | Topic 3 | **Topic 4** | Topic 5

## Characterising Biological Parts

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# Introduction to Synthetic Biology

Topic 1 | Topic 2 | Topic 3 | Topic 4 | **Topic 5**

## Building Systems from BioBricks

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Bioengineering Department
Imperial College London

# Be Aware

Science in the Making

HELP WANTED

Cutting Edge Research

# Introduction to Synthetic Biology

Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5

## Foundations for Synthetic Biology

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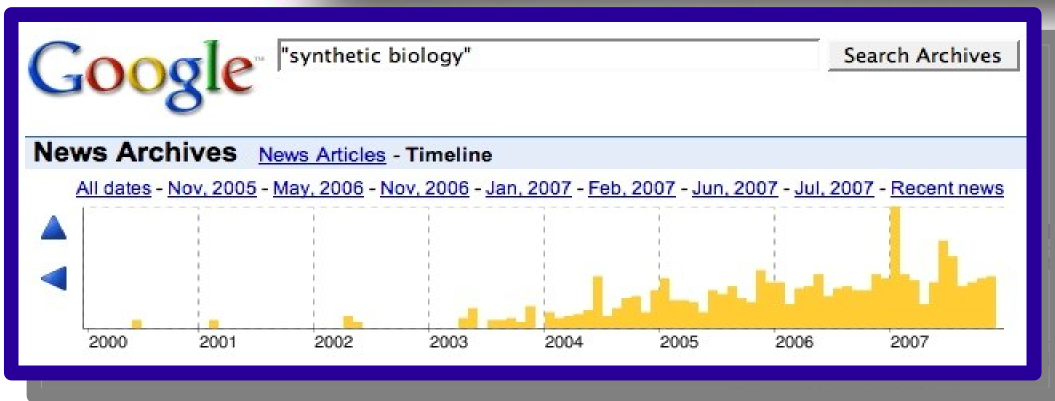
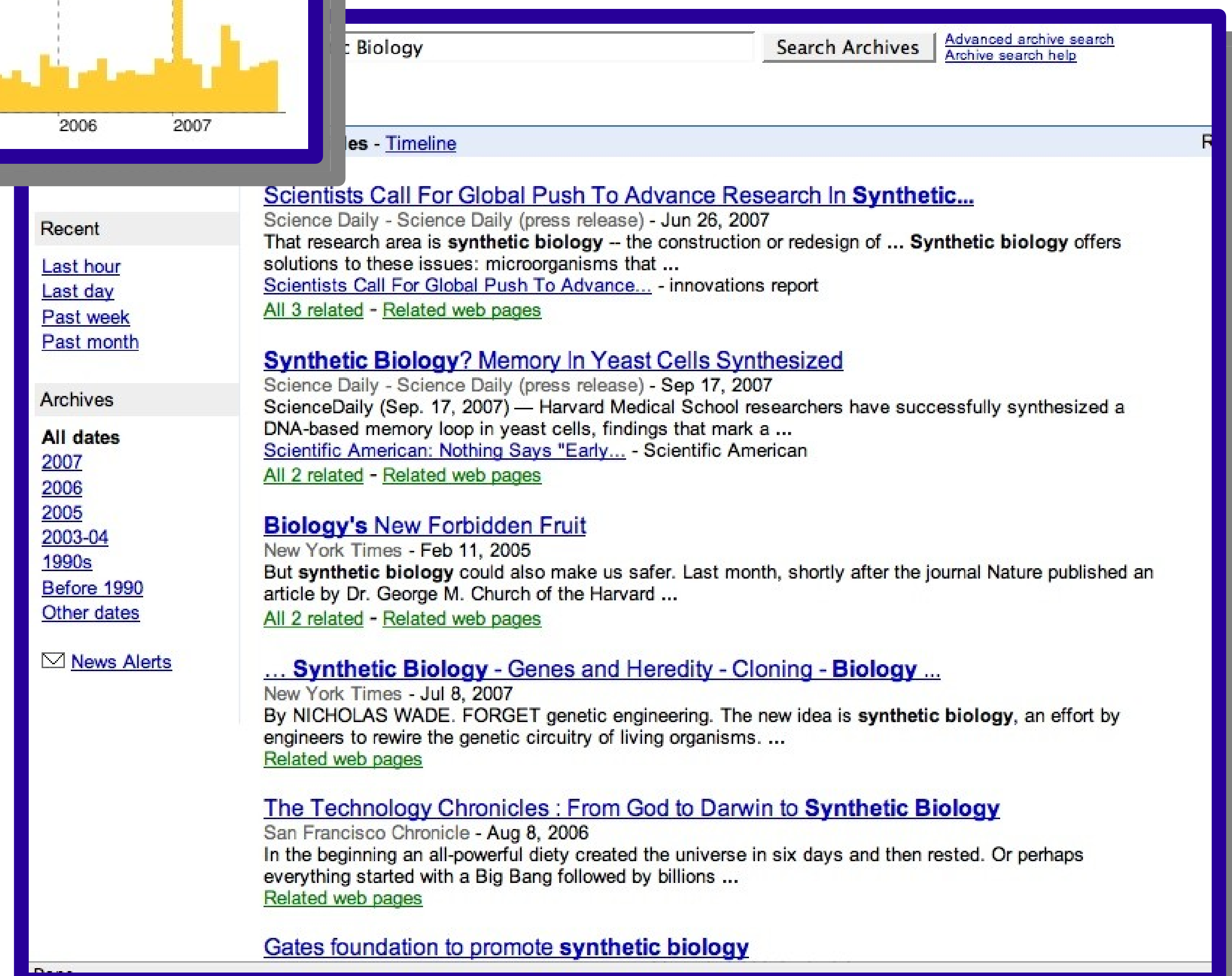
Press Review → Current Research → Finding our SB Definition → SB Principles → Ethics & Society

# Press Review



# Press Review: Main Stream

PRINT EDITION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Special Report Get article

Synthetic biology

## Life 2.0

Aug 31st 2006 | BERKELEY, CAMBRI

From *The Economist* print edition

**The new science of synthetic**
**its time will soon come**

Forbes.com

## Architect of Life

Matthew Herper 10.02.06

**Drew Endy aims to reinvent the biotechnology industry.**

To Drew Endy, all the great breakthroughs in biotechnology of th killing crops and glowing fish--they're simply the result of moving precisely, to rewrite DNA one unit at a time, using this genetic d succeeds it will change the way mankind interacts with the living

The 36-year-old professor at Massachusetts Institute of Technol genetic material, much as bits of mortar or silicon are used to er these wonderful living objects that make copies of themselves, t

In coming years, Endy says, we'll begin to see the first custom-c tumor cells. These "devices" will guard against disease, create r very early days; scientists do not know how to build such device micromachines.

Endy, along with three synthetic-biology comrades, started a co $13 million in backing from Flagship Ventures and three other fir intends to produce its own creations, but that accomplishment is

Initially Codon's goal is to dominate the gene-synthesis market. recently shipped the biggest piece of DNA ever made, a hunk of

Codon claims it will have more production capacity by year-end t 1999, and DNA 2.0, founded in 2003, both of which also deliver D Codon.

Economist.com


Economist, Aug 2006

Synthetic biology

## Playing demigods

Aug 31st 2006
From The Economist print edition

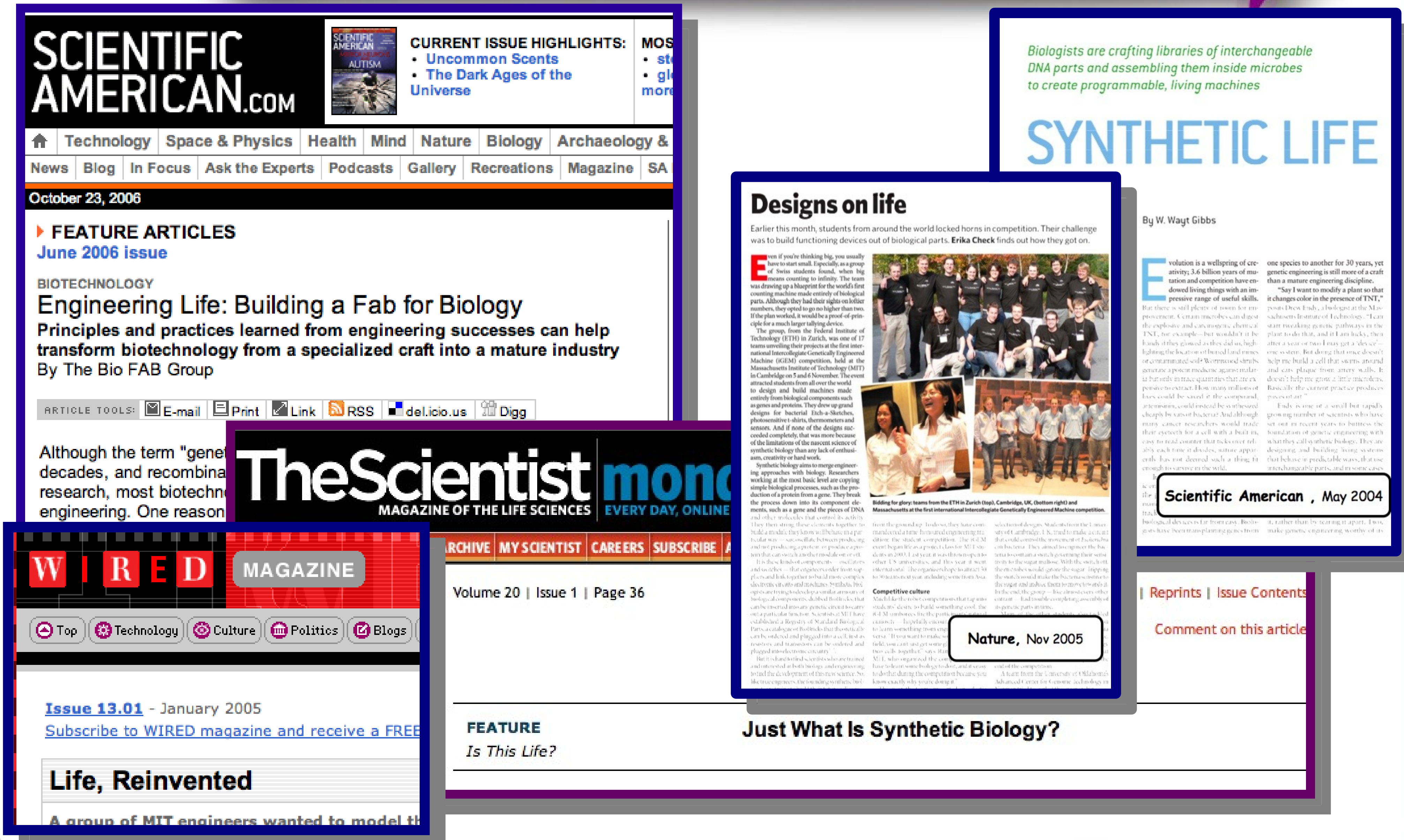
**Synthetic biology needs to be monitored, but not stifled**

THERE will be no thunderstorm, no bolts of lightning channelled through giant switchgear, and definitely no hunchbacks called Igor. But sometime soon a line will be crossed in a laboratory somewhere and the first unarguably living thing created from scratch by the hand of man will divide itself in two and begin to reproduce. When it does so, it will abolish, once and for all, a distinction as old as human thought: that between animate and inanimate matter.

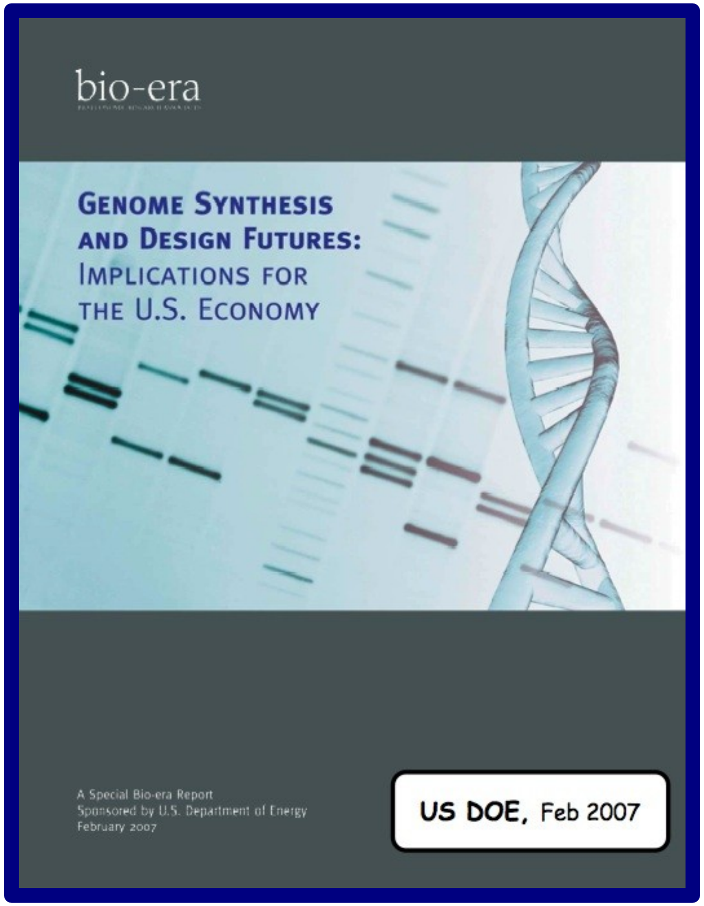
It is not considered polite, in the circles of synthetic biology as the subject is known, to mention the "F" word. Yet behind almost every discussion of the ethics of modern biology lurks the grinning spectre of Mary Shelley's novel, "Frankenstein", a parable on the unintended consequences of creating life. In truth, there is not much that is ethically dubious about making a bacterium from scratch. Making life is less worrying than modifying life—and modifying it in ways that are accidentally or deliberately harmful to mankind.

Synthetic biology is more than the mere tinkering of biotechnology. That just moves single genes around. Synthetic biologists plan to move lots of genes and to industrialise the process in a way that will let people order biological parts as routinely as they order electrical components. If this vision is realised (and there is still a long way to go) biotechnology will become a true branch of engineering, with benefits for industry, medicine and agriculture (see article and article). But biotechnology will also become a game that almost anyone can play—for fun or profit, recklessly or responsibly, for good or ill.

# Press Review: Science/Tech



# Press Review: Govt Institutions




# Seminal Research Papers

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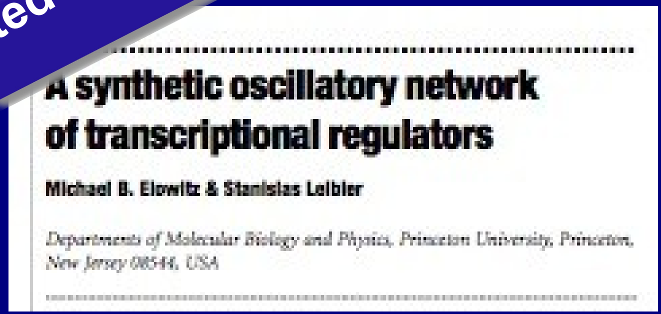
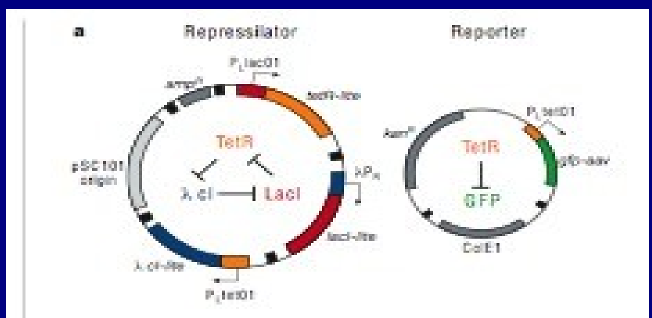
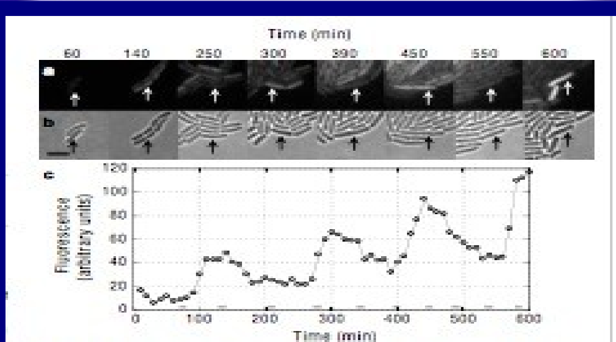


**A synthetic oscillatory network of transcriptional regulators**

**Michael B. Elowitz & Stanislas Leibler**

*Departments of Molecular Biology and Physics, Princeton University, Princeton, New Jersey 08544, USA*




year 2000

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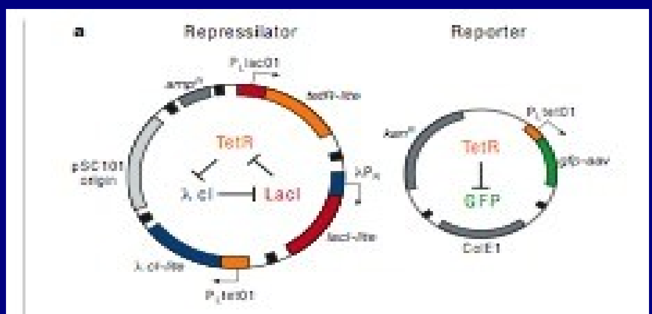


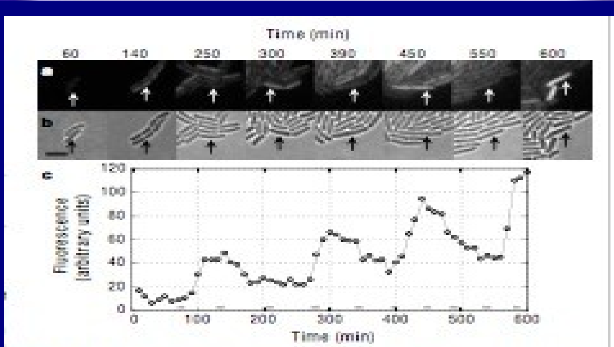


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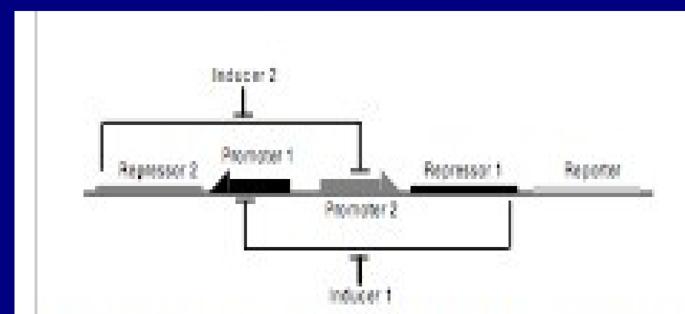
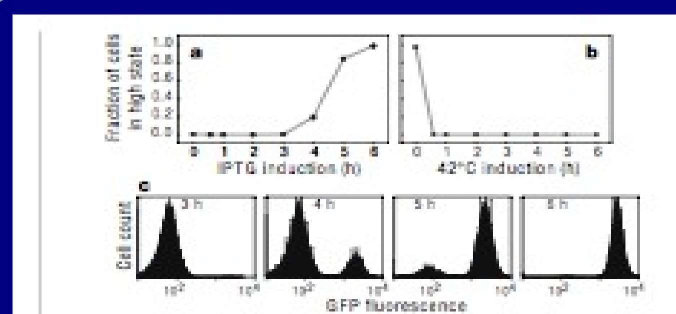
**Construction of a genetic toggle switch in *Escherichia coli***

Timothy S. Gardner*†, Charles R. Cantor* & James J. Collins*†

* *Department of Biomedical Engineering, † Center for BioDynamics and ‡ Center for Advanced Biotechnology, Boston University, 44 Cummington Street, Boston, Massachusetts 02215, USA*




year 2000

# Science in the Making

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synthetic Biology | since 2001 | Search

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- T Ray
- J Kim
- E Marcotte
- I Lee
- T Fox

An evolutionary approach to **synthetic biology**: zen in the art of creating life - group of 6 »
TS Ray - Natural Computing Series, 2003 - portal.acm.org
... An evolutionary approach to **synthetic biology**: zen in the art of creating life. Source, Natural Computing Series archive Advances ...
Cited by 118 - Related Articles - Web Search - SFX@Imperial

**Synthetic biology**: engineering Escherichia coli to see light. - SFX@Imperial - group of 3 »
A Levskaya, AA Chevalier, JJ Tabor, ZB Simpson, LA ... - Nature, 2005 - ncbi.nlm.nih.gov
Nature. 2005 Nov 24;438(7067):441-2. Click here to read **Synthetic biology**: engineering Escherichia coli to see light. Levskaya A ...
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**Synthetic biology**: Building up a picture of gene regulation - SFX@Imperial
M Skipper - Nature Reviews Genetics, 2006 - nature.com
... Nature Reviews Genetics 7, 242-243 (April 2006) | doi :10.1038/nrg1844. **Synthetic biology**: Building up a picture of gene regulation. Magdalena Skipper. ...
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**Synthetic biology**: Designs on life - SFX@Imperial - group of 3 »
E CHECK - Nature, 2005 - nature.com
... 438417a. **Synthetic biology**: Designs on life. Erika ... **Synthetic biology** aims to merge engineering approaches with **biology**. Researchers working ...
Related Articles - Cached - Web Search - BL Direct

How **synthetic biology** can avoid GMO-style conflicts. - SFX@Imperial
M Tepfer - Nature, 2005 - ncbi.nlm.nih.gov
Comment on: Nature. 2005 Aug 18;436(7053):894-5. Click here to read How **synthetic biology** can avoid GMO-style conflicts. Tepfer ...
Cached - Web Search

RNA **synthetic biology**.
FJ Isaacs, DJ Dwyer, JJ Collins - Nat Biotechnol, 2005 - ncbi.nlm.nih.gov

**Nature**

**PNAS**

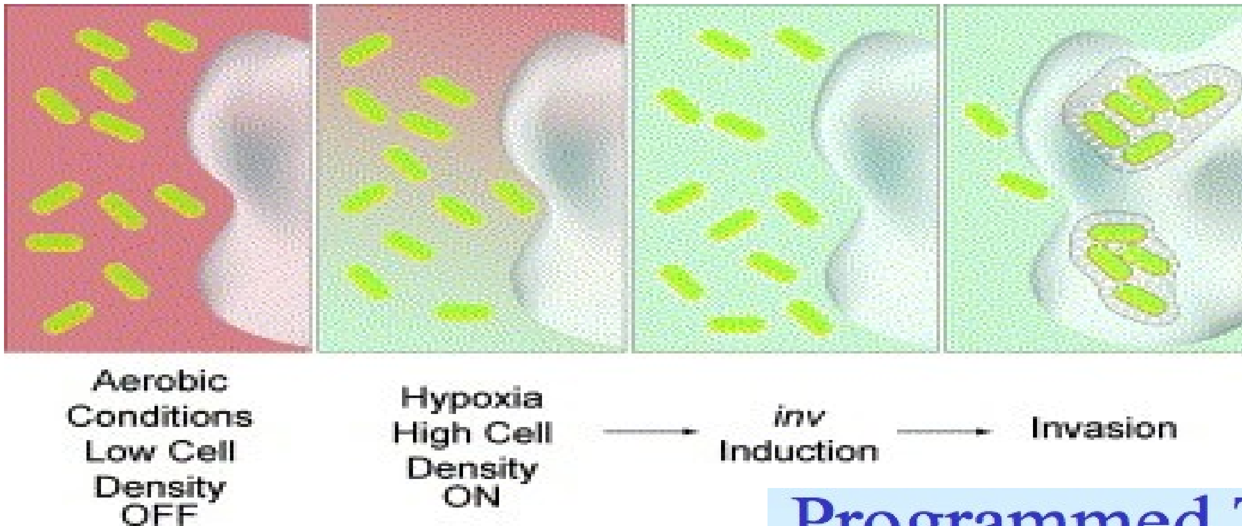
**Biotechnol.**

**Nat. Computing.**

**Chem. Eng**

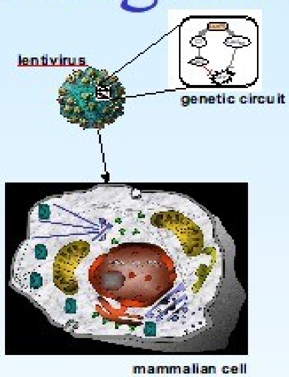
# Current Research: Biomedical

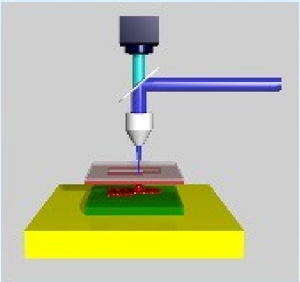
**Tumor-Killing Bacteria, JC Anderson et al, 2004.**

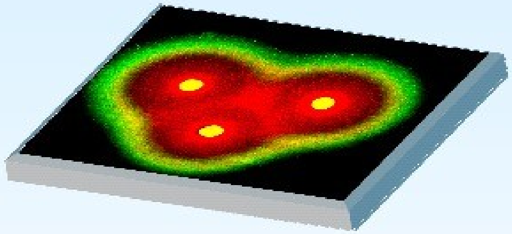



## Programmed Tissue (Re)generation

Ron Weiss' Lab, Princeton.





Step #1:
genetically engineer new communication & differentiation pathways

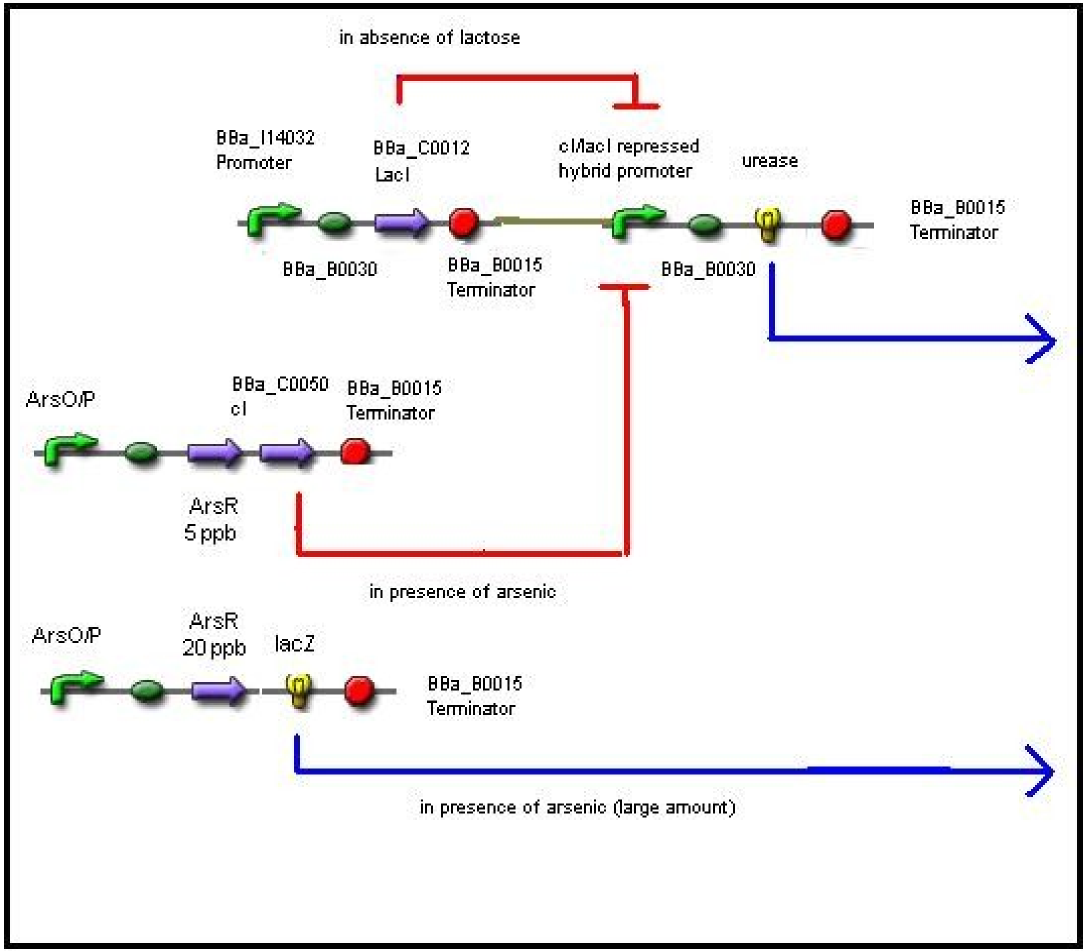
Step #2:
Laser Direct Write* of cells onto a substrate

Step #3:
pattern formation and tissue generation based on engineered cell-cell communication

* Collaboration with Craig Arnold's Lab

# Current Research: Environment

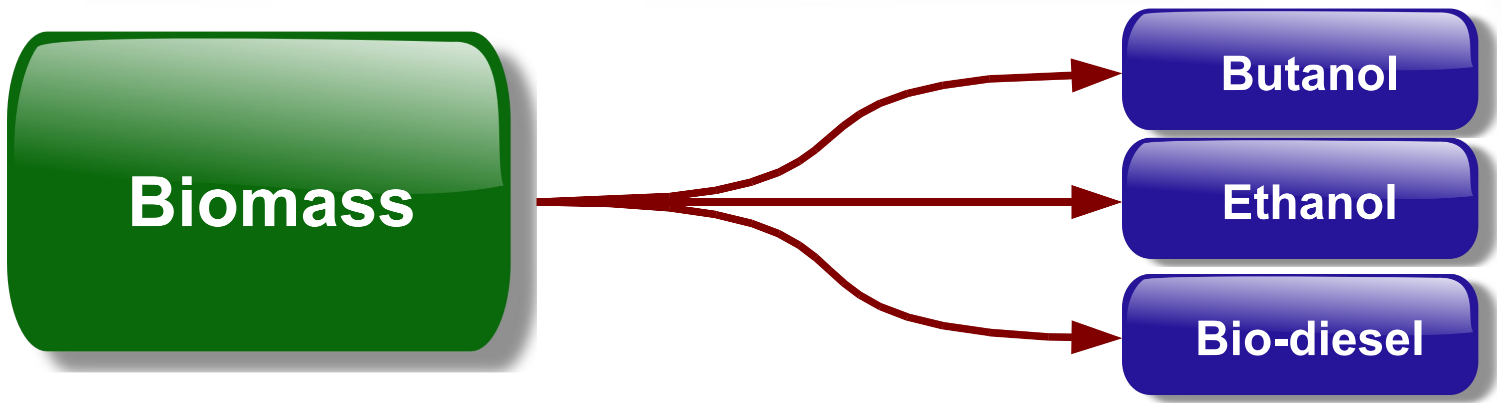
INPUT
ARSENIC
CONCENTRATI ON




OUTPUT
pH CHANGE

**Arsenic Biosensor, iGEM 2006, Edinburgh Team**

# Current Research: Bio-Energy

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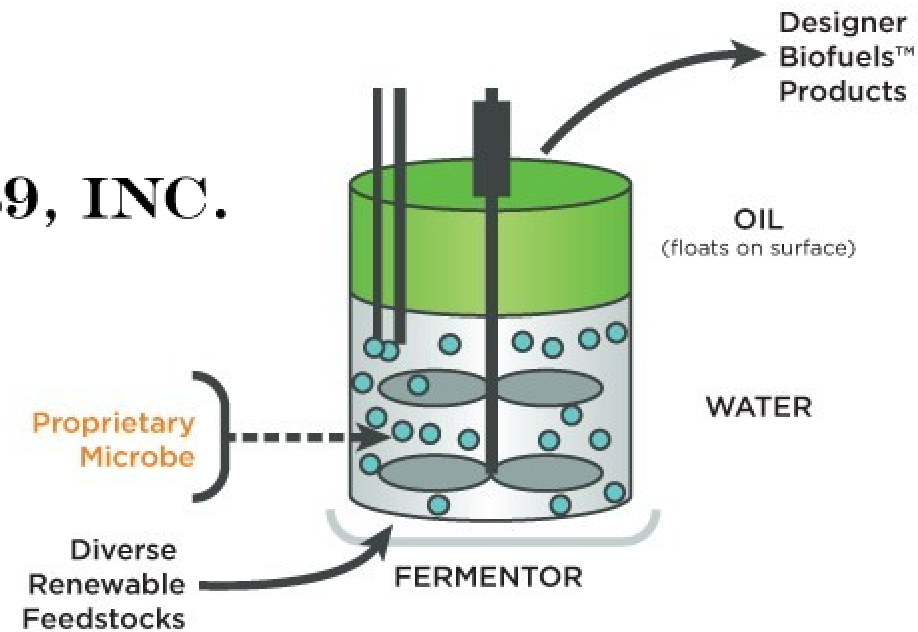
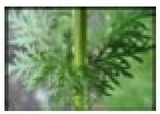


# Current Research: Drug Development

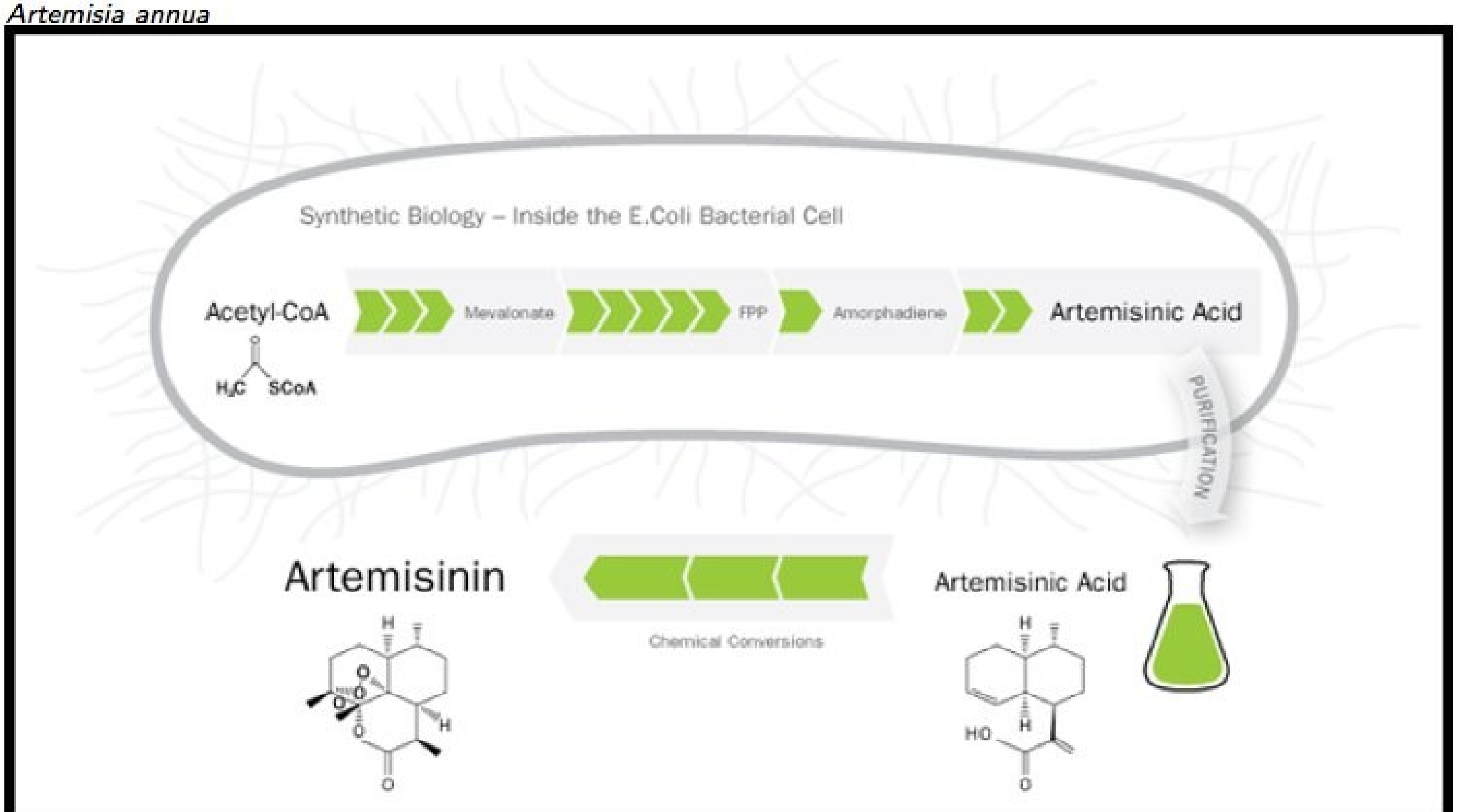
## Bacterial drug factories



AMYRIS BIOTECHNOLOGIES

iOWH Institute for OneWorld Health
A Nonprofit Pharmaceutical Company

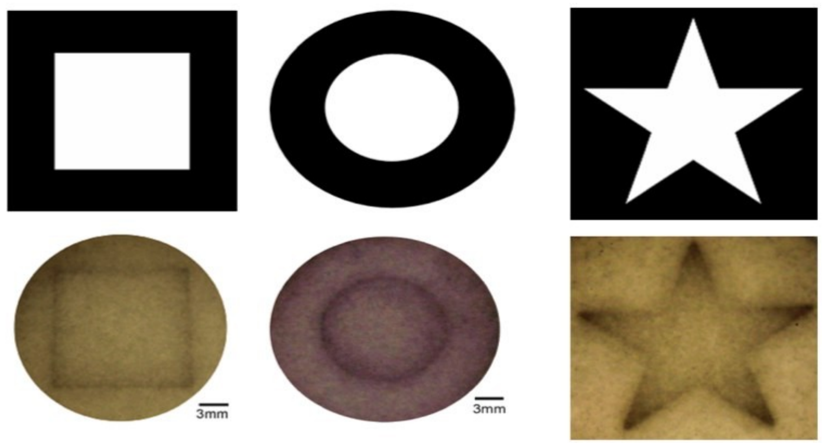
*Artemisia annua*




* from Austin Che's presentation

# Current Research: Information Processing

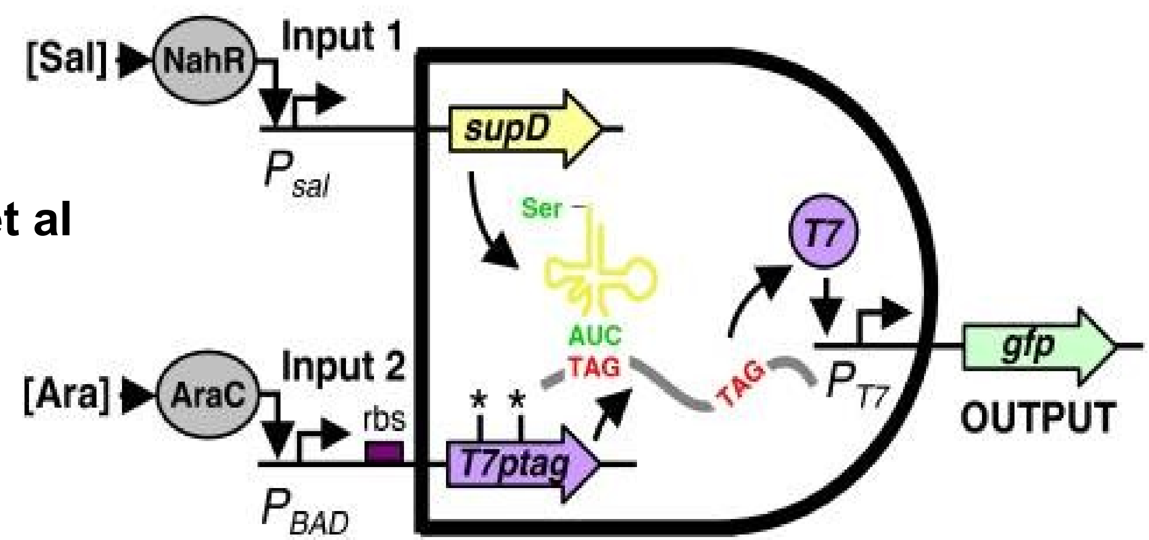
Bacterial signal processing for edge detection




Jeff Tabor

**"Bacterial Edge Detector", Jeffrey Tabor**

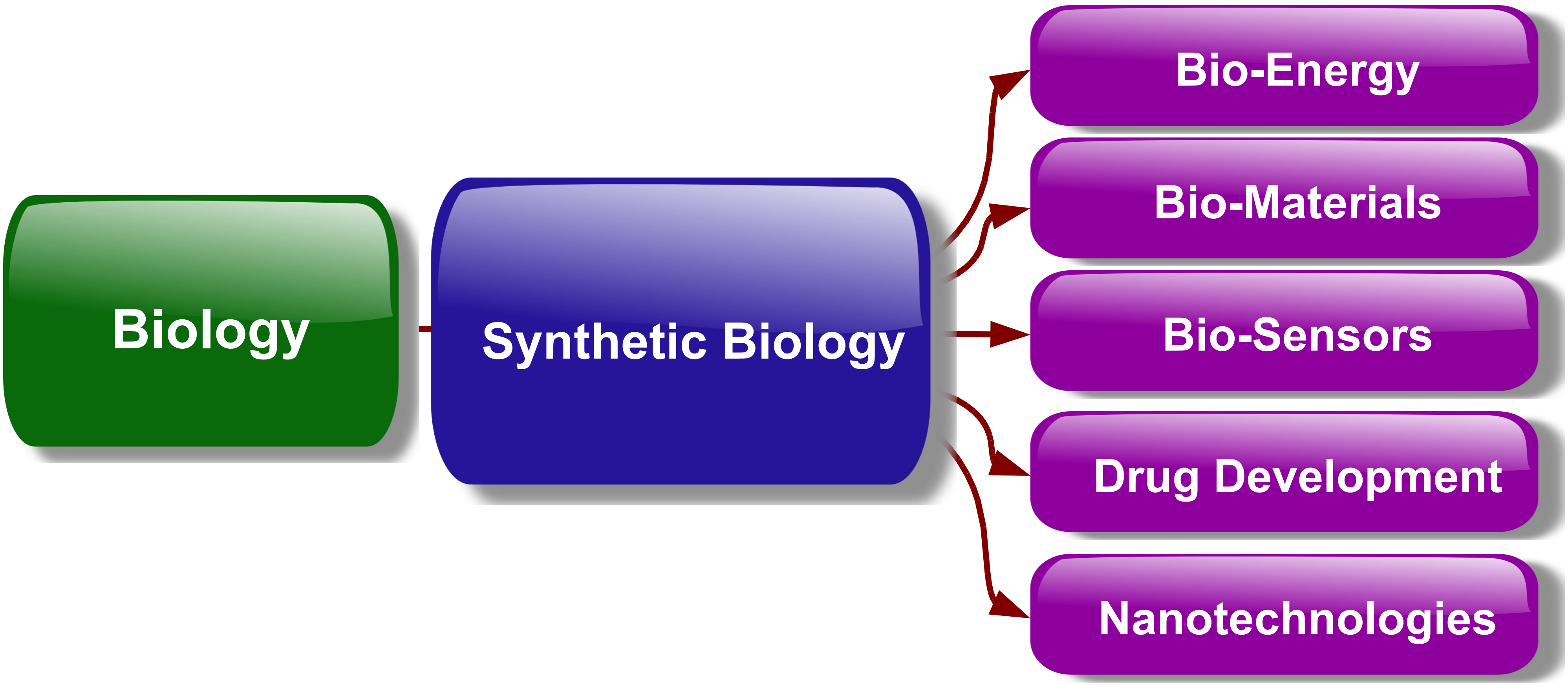
**"AND Gate", JC Anderson et al**



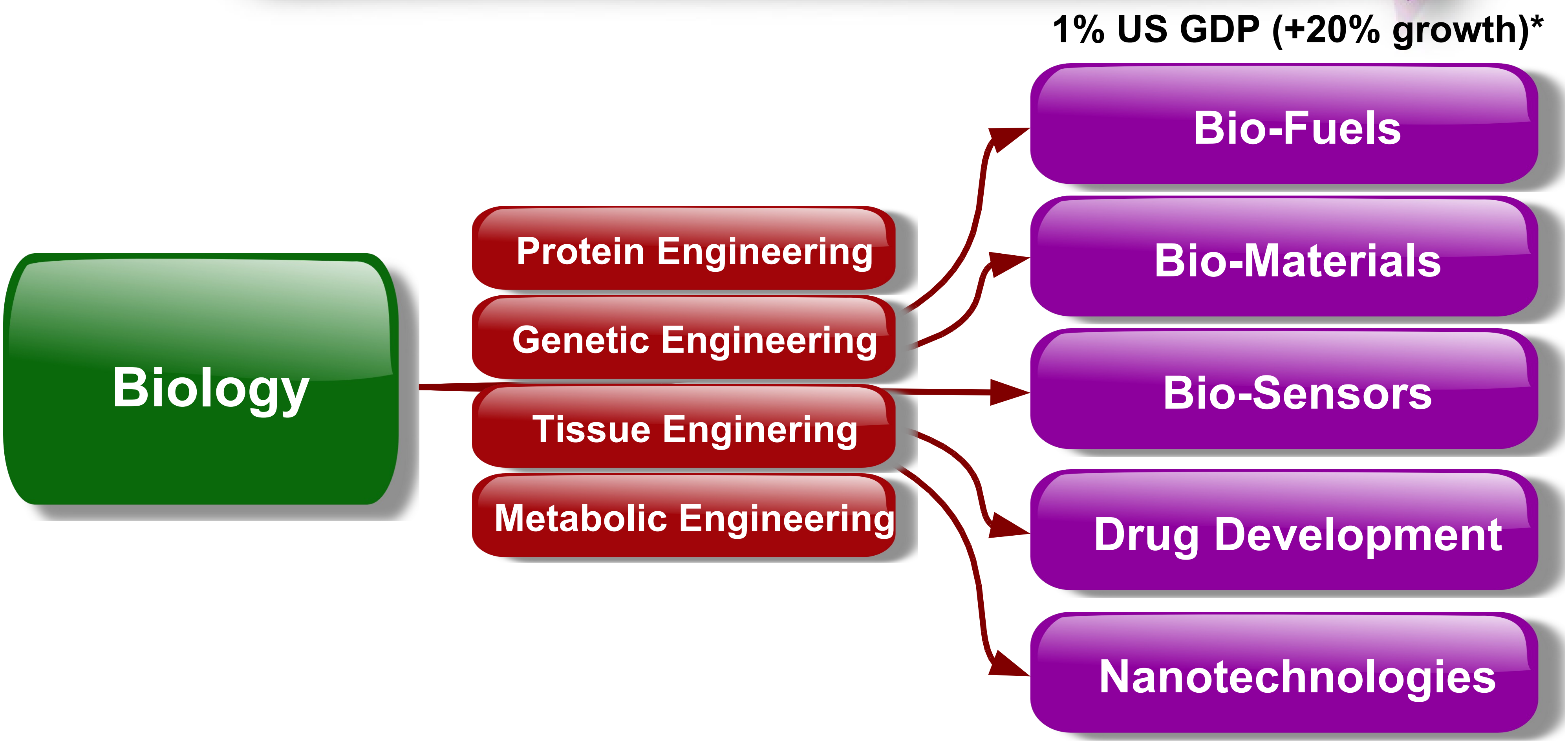
# Synthetic Biology Definition

...

# Defined by its areas of application ?



# Defined by its areas of application ?




* Carlson, 2008.

# Defined by its technological platform ?

**Synthetic Biology Toolbox**

- **Recombinant DNA**
  **Cloning – Directed Evolution**
- **High-throughput technologies (NMR, micro-arrays, automation)**
- **DNA Sequencing**
  **DNA Synthesis**
- **Computational Modelling**

# Defined by its technological platform ?

**Synthetic Biology Toolbox**

- Protein Engineering
- Tissue Enginering
- Genetic Engineering
- Metabolic Engineering

- Recombinant DNA

  Cloning – Directed Evolution
- High-throughput technologies (NMR, micro-arrays, automation)
- DNA Sequencing

  DNA Synthesis
- Computational Modelling

# SyntheticBiology.org

## Synthetic Biology

**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.

(Español)

# SyntheticBiology.org

## Synthetic Biology

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.

(Español)

**Protein Engineering** | **Tissue Engineering**

**Genetic Engineering** | **Metabolic Engineering**

# iGEM Perspective

## iGEM - The international Genetically Engineered Machine competition

?

**iGEM addresses the question:** Can simple biological systems be built from standard, interchangeable parts and operated in living cells? Or is biology simply too complicated to be engineered in this way?

www.parts.mit.edu/wiki

# iGEM Perspective

**iGEM** - The international Genetically Engineered Machine competition

> **iGEM addresses the question:** Can simple biological systems be built from standard, interchangeable parts and operated in living cells? Or is biology simply too complicated to be engineered in this way?
>
> www.parts.mit.edu/wiki

## True Engineering Approach to Biology

**Standard** | **Interchangeable** | **Parts**

~~Protein Engineering~~ | ~~Tissue Engineering~~

~~Genetic Engineering~~ | ~~Metabolic Engineering~~

# Engineering Approach

## Industrial Revolutions

### Mechanical

Machine Tool

Nuts & Bolts

### Transport

Trains

Car / Road

### Chemical

Large scale production

### Digital

Hardware

Communication protocols

File Format

# Engineering Approach

**Abstraction** | **Standardisation** | **Quality Control**

## Industrial Revolutions

### Mechanical

Machine Tool

Nuts & Bolts

### Transport

Trains

Car / Road

### Chemical

Large scale production

### Digital

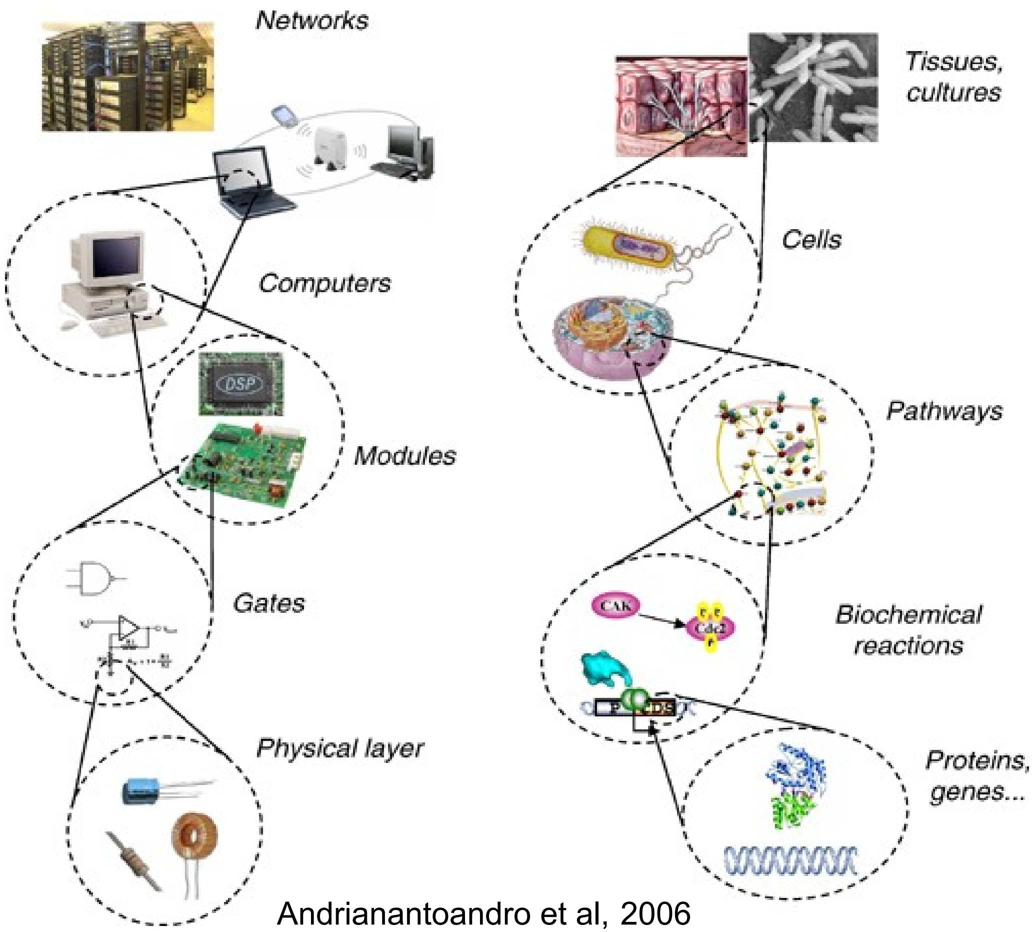
Hardware

Communication protocols

File Format

# Abstraction Principle

**Abstraction** | **Standardisation** | **Quality Control**




Andrianantoandro et al, 2006

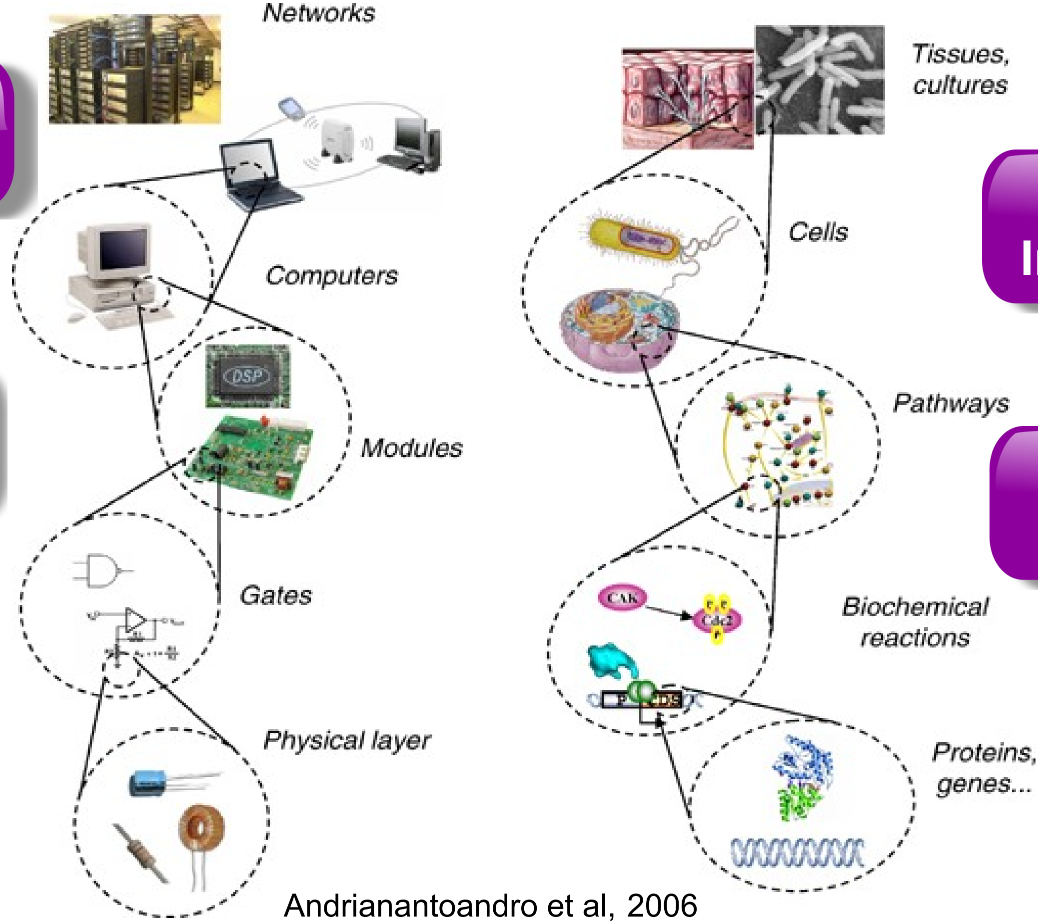
# Abstraction Principle

**Abstraction** | **Standardisation** | **Quality Control**

**Break down complexity**

**Abstraction Hierarchy**

**Abstraction Layer**




Andrianantoandro et al, 2006

**Modularity Inputs / Outputs**

**Decoupling**

# Abstraction Principle for SB

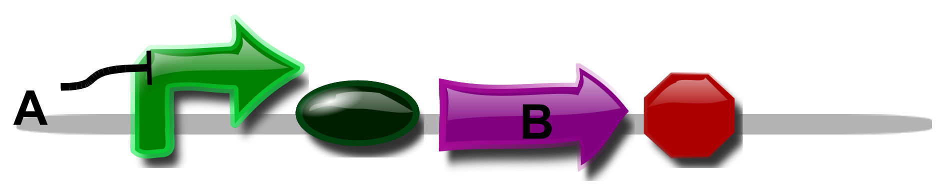
**Abstraction** | **Standardisation** | **Quality Control**

**DNA** ACACTTCAAACCAAACCTTATTTCTAATTGAGAAGGGCCGGTTGA

# Abstraction Principle for SB

**Abstraction** | **Standardisation** | **Quality Control**

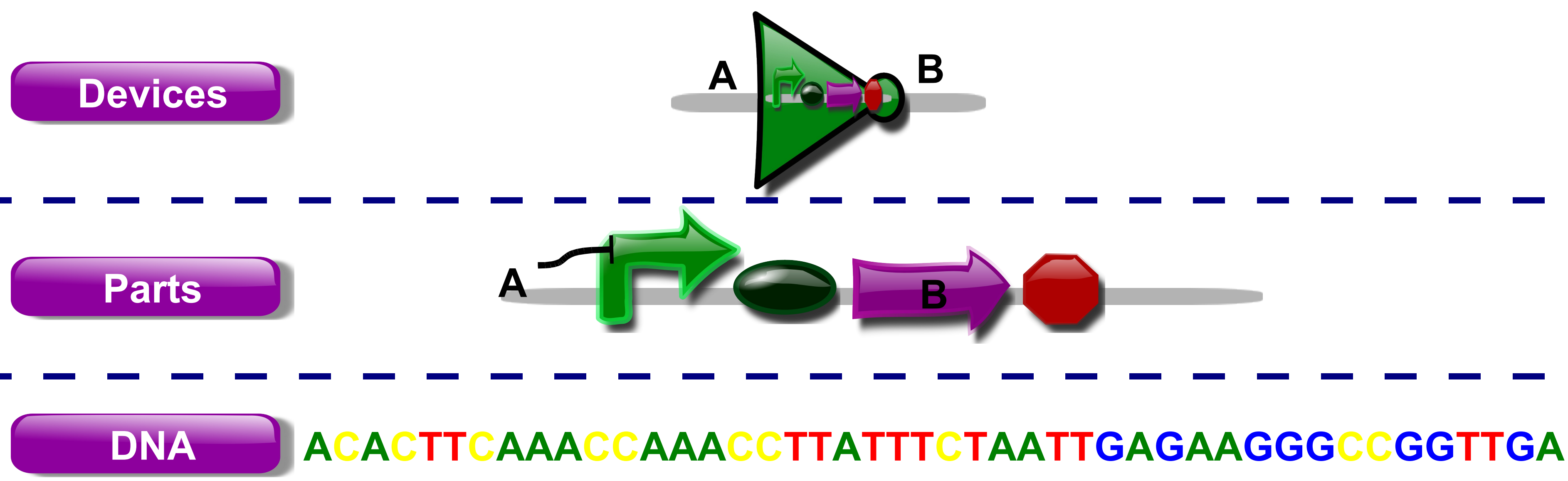
**Parts**



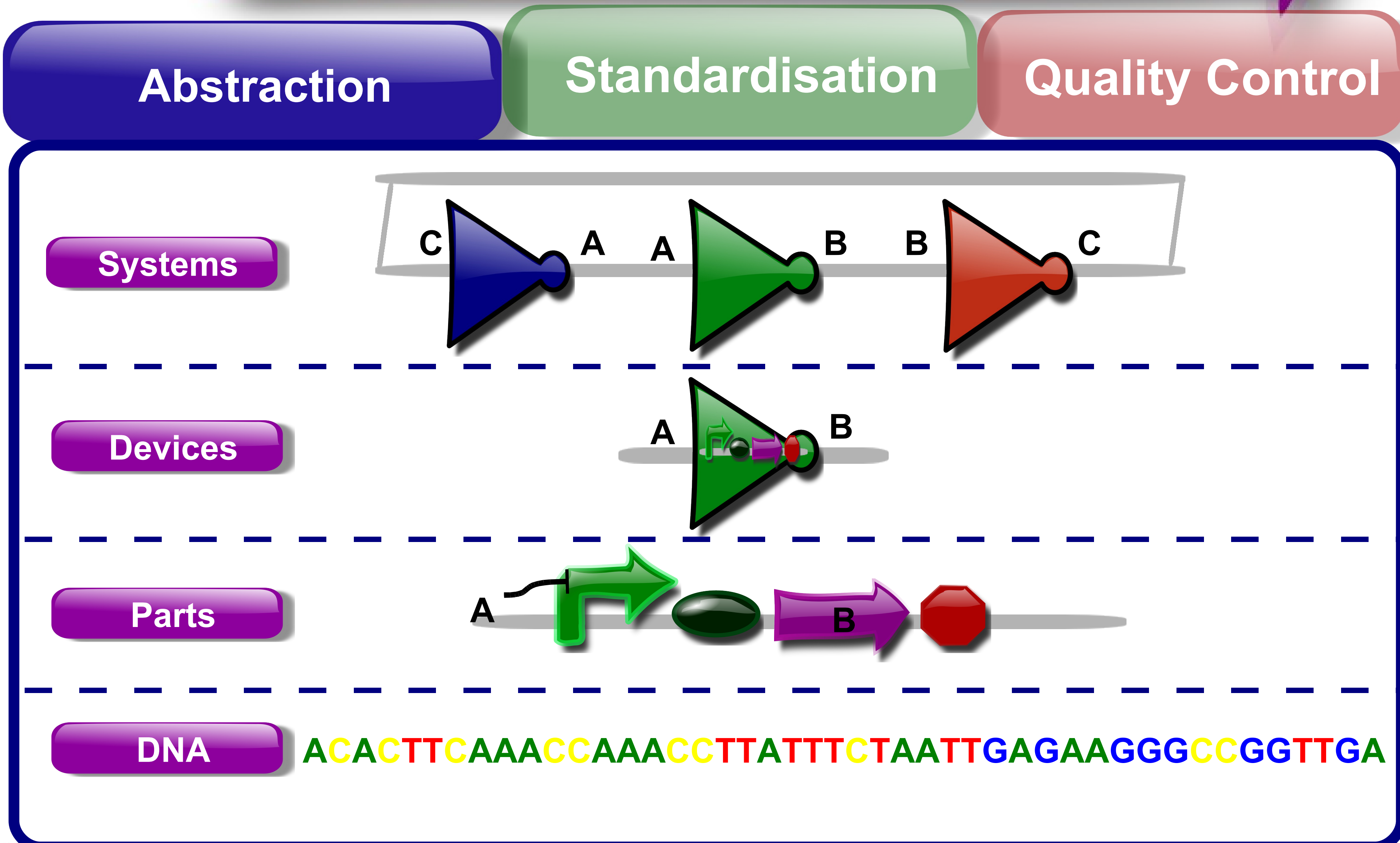

**DNA** ACACTTCAAACCAAACCTTATTTCTAATTGAGAAGGGCCGGTTGA

# Abstraction Principle for SB

**Abstraction** | **Standardisation** | **Quality Control**

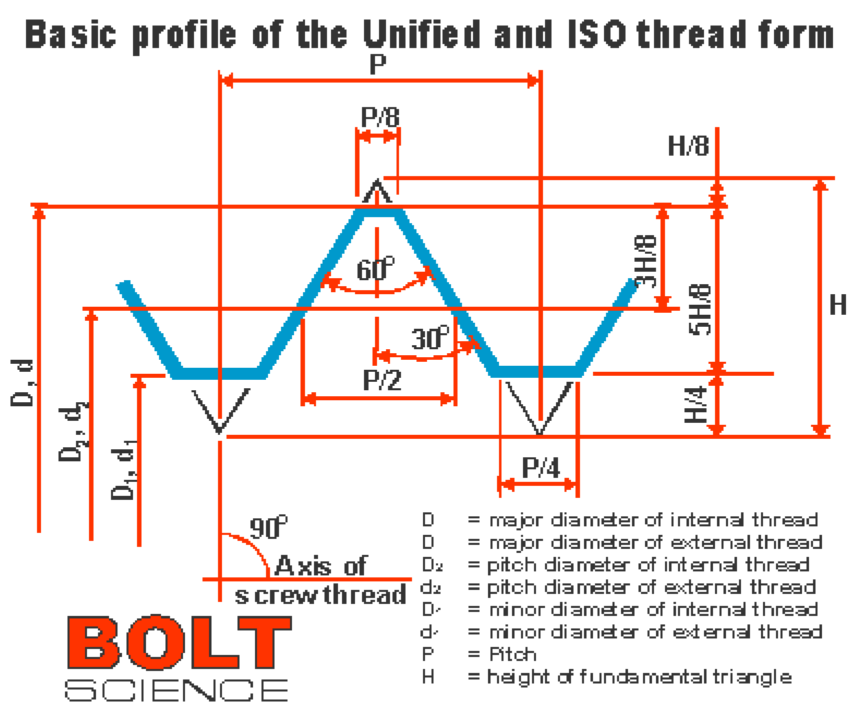


# Abstraction Principle for SB



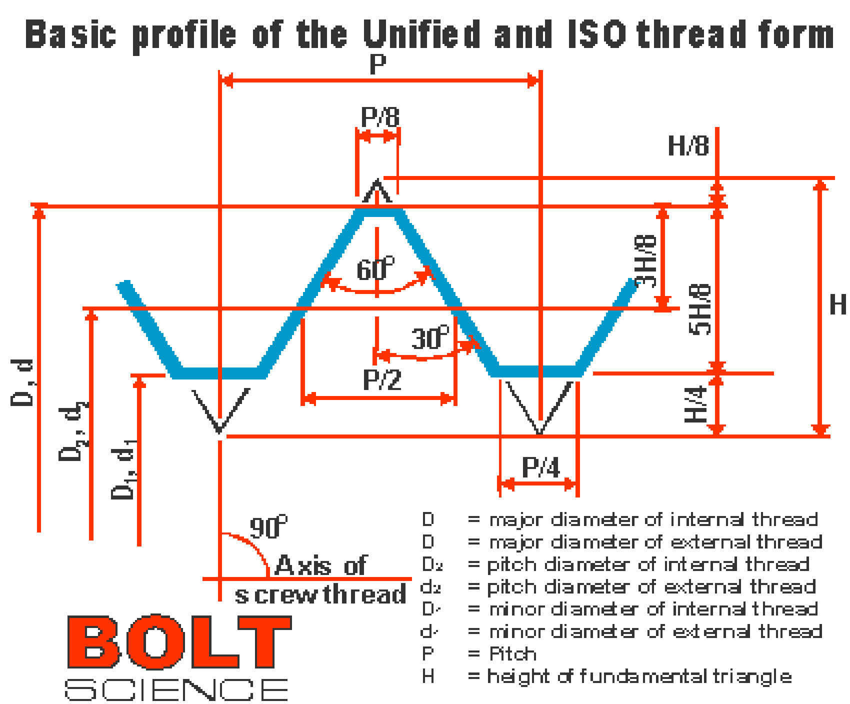
# Standardisation Principle

**Abstraction** | **Standardisation** | **Quality Control**



# Standardisation Principle

Abstraction | **Standardisation** | Quality Control




Uniform and agreed | Inter-operability | Re-usability | Economical Benefits

# Standardisation Principles for SB

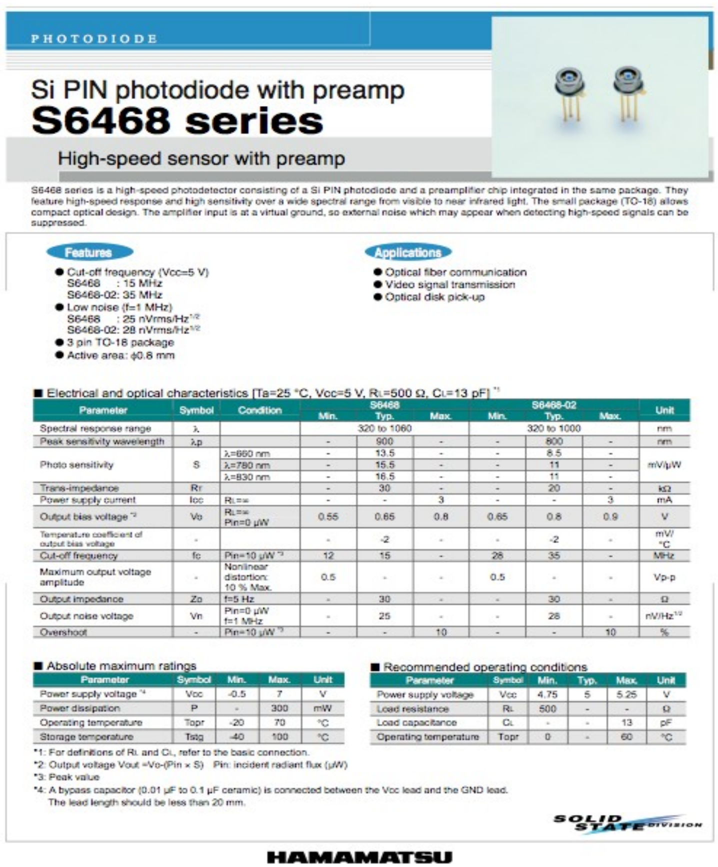
Abstraction | **Standardisation** | Quality Control

- Standard Physical DNA composition → Topic 2
- Standards Functional Composition → Topic 3
- Standard Culture Conditions
- Standard Measurements
- Standard Cell Host (Chassis)

→ Topic 4 + Practical

# Quality Control Principle

**Abstraction** | **Standardisation** | **Quality Control**



PHOTODIODE

# Si PIN photodiode with preamp
# S6468 series

## High-speed sensor with preamp

S6468 series is a high-speed photodetector consisting of a Si PIN photodiode and a preamplifier chip integrated in the same package. They feature high-speed response and high sensitivity over a wide spectral range from visible to near infrared light. The small package (TO-18) allows compact optical design. The amplifier input is at a virtual ground, so external noise which may appear when detecting high-speed signals can be suppressed.

**Features**
- Cut-off frequency (Vcc=5 V)
  S6468 : 15 MHz
  S6468-02: 35 MHz
- Low noise (f=1 MHz)
  S6468 : 25 nVrms/Hz$^{1/2}$
  S6468-02: 28 nVrms/Hz$^{1/2}$
- 3 pin TO-18 package
- Active area: ϕ0.8 mm

**Applications**
- Optical fiber communication
- Video signal transmission
- Optical disk pick-up

■ Electrical and optical characteristics [Ta=25 °C, Vcc=5 V, $R_L$=500 Ω, $C_L$=13 pF] *1

| Parameter | Symbol | Condition | S6468 Min. | S6468 Typ. | S6468 Max. | S6468-02 Min. | S6468-02 Typ. | S6468-02 Max. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Spectral response range | λ | | | 320 to 1060 | | | 320 to 1000 | | nm |
| Peak sensitivity wavelength | λp | | - | 900 | - | - | 800 | - | nm |
| Photo sensitivity | S | λ=660 nm | - | 13.5 | - | - | 8.5 | - | mV/μW |
| | | λ=780 nm | - | 15.5 | - | - | 11 | - | |
| | | λ=830 nm | - | 16.5 | - | - | 11 | - | |
| Trans-impedance | Rf | | - | 30 | - | - | 20 | - | kΩ |
| Power supply current | Icc | $R_L$=∞ | - | - | 3 | - | - | 3 | mA |
| Output bias voltage *2 | Vo | $R_L$=∞ Pin=0 μW | 0.55 | 0.65 | 0.8 | 0.65 | 0.8 | 0.9 | V |
| Temperature coefficient of output bias voltage | - | | - | -2 | - | - | -2 | - | mV/°C |
| Cut-off frequency | fc | Pin=10 μW *3 | 12 | 15 | - | 28 | 35 | - | MHz |
| Maximum output voltage amplitude | - | Nonlinear distortion: 10 % Max. | 0.5 | - | - | 0.5 | - | - | Vp-p |
| Output impedance | Zo | f=5 Hz | - | 30 | - | - | 30 | - | Ω |
| Output noise voltage | Vn | Pin=0 μW f=1 MHz | - | 25 | - | - | 28 | - | nV/Hz$^{1/2}$ |
| Overshoot | - | Pin=10 μW *3 | - | - | 10 | - | - | 10 | % |

■ Absolute maximum ratings

| Parameter | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|
| Power supply voltage *4 | Vcc | -0.5 | 7 | V |
| Power dissipation | P | - | 300 | mW |
| Operating temperature | Topr | -20 | 70 | °C |
| Storage temperature | Tstg | -40 | 100 | °C |

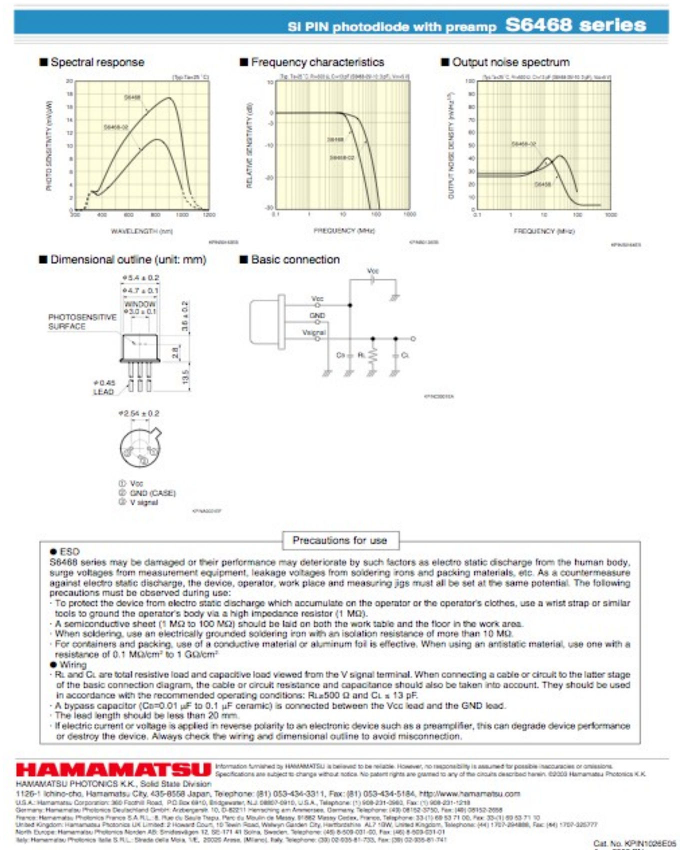
■ Recommended operating conditions

| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Power supply voltage | Vcc | 4.75 | 5 | 5.25 | V |
| Load resistance | $R_L$ | 500 | - | - | Ω |
| Load capacitance | $C_L$ | - | - | 13 | pF |
| Operating temperature | Topr | 0 | - | 60 | °C |

*1: For definitions of $R_L$ and $C_L$, refer to the basic connection.
*2: Output voltage Vout =Vo-(Pin × S) Pin: incident radiant flux (μW)
*3: Peak value
*4: A bypass capacitor (0.01 μF to 0.1 μF ceramic) is connected between the Vcc lead and the GND lead. The lead length should be less than 20 mm.

SOLID STATE DIVISION

HAMAMATSU



Si PIN photodiode with preamp **S6468 series**

■ Spectral response

■ Frequency characteristics

■ Output noise spectrum

■ Dimensional outline (unit: mm)

① Vcc
② GND (CASE)
③ V signal

■ Basic connection

**Precautions for use**

- ESD

S6468 series may be damaged or their performance may deteriorate by such factors as electro static discharge from the human body, surge voltages from measurement equipment, leakage voltages from soldering irons and packing materials, etc. As a countermeasure against electro static discharge, the device, operator, work place and measuring jigs must all be set at the same potential. The following precautions must be observed during use:
· To protect the device from electro static discharge which accumulate on the operator or the operator's clothes, use a wrist strap or similar tools to ground the operator's body via a high impedance resistor (1 MΩ).
· A semiconductive sheet (1 MΩ to 100 MΩ) should be laid on both the work table and the floor in the work area.
· When soldering, use an electrically grounded soldering iron with an isolation resistance of more than 10 MΩ.
· For containers and packing, use of a conductive material or aluminum foil is effective. When using an antistatic material, use one with a resistance of 0.1 MΩ/cm² to 1 GΩ/cm²

- Wiring

· $R_L$ and $C_L$ are total resistive load and capacitive load viewed from the V signal terminal. When connecting a cable or circuit to the latter stage of the basic connection diagram, the cable or circuit resistance and capacitance should also be taken into account. They should be used in accordance with the recommended operating conditions: $R_L$≥500 Ω and $C_L$ ≤ 13 pF.
· A bypass capacitor ($C_B$=0.01 μF to 0.1 μF ceramic) is connected between the Vcc lead and the GND lead.
· The lead length should be less than 20 mm.
· If electric current or voltage is applied in reverse polarity to an electronic device such as a preamplifier, this can degrade device performance or destroy the device. Always check the wiring and dimensional outline to avoid misconnection.

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1126-1 Ichino-cho, Hamamatsu City, 435-8558 Japan, Telephone: (81) 053-434-3311, Fax: (81) 053-434-5184, http://www.hamamatsu.com

# Quality Control Principle

**Abstraction** | **Standardisation** | **Quality Control**

PHOTODIODE

## Si PIN photodiode with preamp
# S6468 series

High-speed sensor with preamp

S6468 series is a high-speed photodetector consisting of a Si PIN photodiode and a preamplifier chip integrated in the same package. They feature high-speed response and high sensitivity over a wide spectral range from visible to near infrared light. The small package (TO-18) allows compact optical design. The amplifier input is at a virtual ground, so external noise which may appear when detecting high-speed signals can be suppressed.

**Features**
- Cut-off frequency (Vcc=5 V)
  S6468 : 15 MHz
  S6468-02: 35 MHz
- Low noise (f=1 MHz)
  S6468 : 25 nVrms/$Hz^{1/2}$
  S6468-02: 28 nVrms/$Hz^{1/2}$
- 3 pin TO-18 package
- Active area: ϕ0.8 mm

**Applications**
- Optical fiber communication
- Video signal transmission
- Optical disk pick-up

■ Electrical and optical characteristics [Ta=25 °C, Vcc=5 V, $R_L$=500 Ω, $C_L$=13 pF] *1

| Parameter | Symbol | Condition | S6468 Min. | S6468 Typ. | S6468 Max. | S6468-02 Min. | S6468-02 Typ. | S6468-02 Max. | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Spectral response range | λ | | | 320 to 1060 | | | 320 to 1000 | | nm |
| Peak sensitivity wavelength | λp | | - | 900 | - | - | 800 | - | nm |
| Photo sensitivity | S | λ=660 nm | - | 13.5 | - | - | 8.5 | - | mV/μW |
| | | λ=780 nm | - | 15.5 | - | - | 11 | - | |
| | | λ=830 nm | - | 16.5 | - | - | 11 | - | |
| Trans-impedance | Rf | | - | 30 | - | - | 20 | - | kΩ |
| Power supply current | Icc | $R_L$=∞ | - | - | 3 | - | - | 3 | mA |
| Output bias voltage *2 | Vo | $R_L$=∞ Pin=0 μW | 0.55 | 0.65 | 0.8 | 0.65 | 0.8 | 0.9 | V |
| Temperature coefficient of output bias voltage | - | | - | -2 | - | - | -2 | - | mV/°C |
| Cut-off frequency | fc | Pin=10 μW *3 | 12 | 15 | - | 28 | 35 | - | MHz |
| Maximum output voltage amplitude | - | Nonlinear distortion: 10 % Max. | 0.5 | - | - | 0.5 | - | - | Vp-p |
| Output impedance | Zo | f=5 Hz | - | 30 | - | - | 30 | - | Ω |
| Output noise voltage | Vn | Pin=0 μW f=1 MHz | - | 25 | - | - | 28 | - | nV/$Hz^{1/2}$ |
| Overshoot | - | Pin=10 μW *3 | - | - | 10 | - | - | 10 | % |

■ Absolute maximum ratings

| Parameter | Symbol | Min. | Max. | Unit |
|---|---|---|---|---|
| Power supply voltage *4 | Vcc | -0.5 | 7 | V |
| Power dissipation | P | - | 300 | mW |
| Operating temperature | Topr | -20 | 70 | °C |
| Storage temperature | Tstg | -40 | 100 | °C |

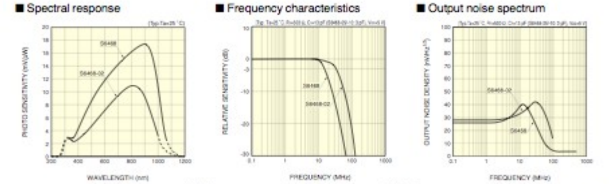
■ Recommended operating conditions

| Parameter | Symbol | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|
| Power supply voltage | Vcc | 4.75 | 5 | 5.25 | V |
| Load resistance | $R_L$ | 500 | - | - | Ω |
| Load capacitance | $C_L$ | - | - | 13 | pF |
| Operating temperature | Topr | 0 | - | 60 | °C |

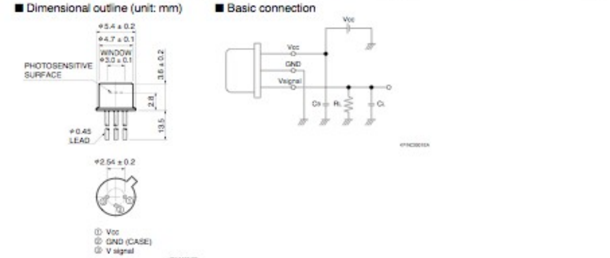
*1: For definitions of $R_L$ and $C_L$, refer to the basic connection.
*2: Output voltage Vout =Vo-(Pin × S) Pin: incident radiant flux (μW)
*3: Peak value
*4: A bypass capacitor (0.01 μF to 0.1 μF ceramic) is connected between the Vcc lead and the GND lead.

Si PIN photodiode with preamp **S6468 series**

■ Spectral response ■ Frequency characteristics ■ Output noise spectrum



■ Dimensional outline (unit: mm) ■ Basic connection

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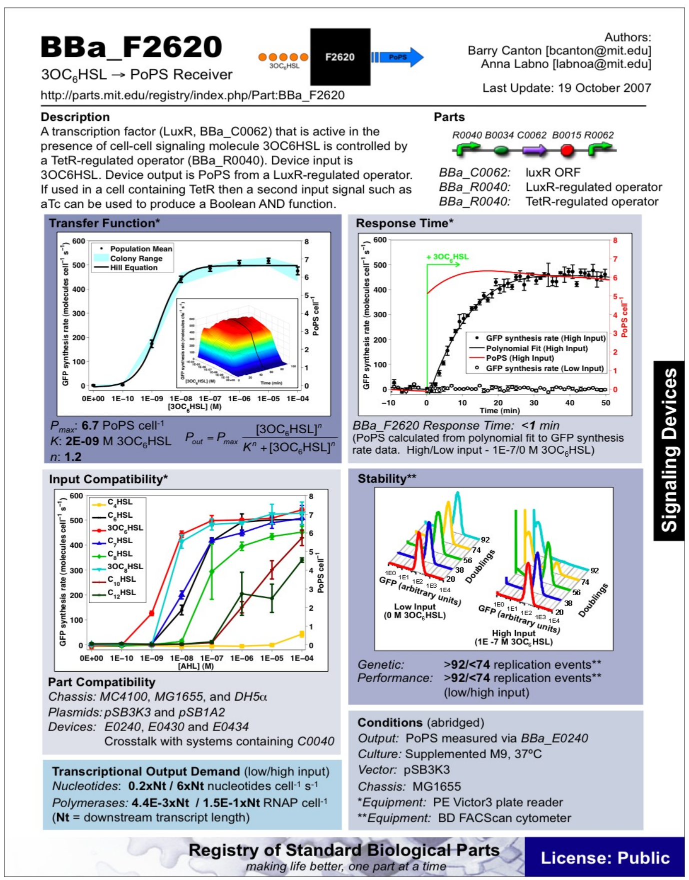
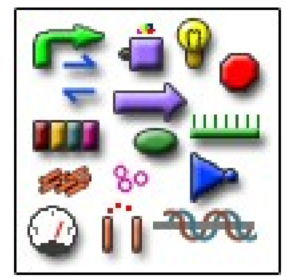
**Specification Sheet** | **Characterisation under Standard Conditions** | **Tolerances / Reliability** | **Trust**

# Quality Control Principle

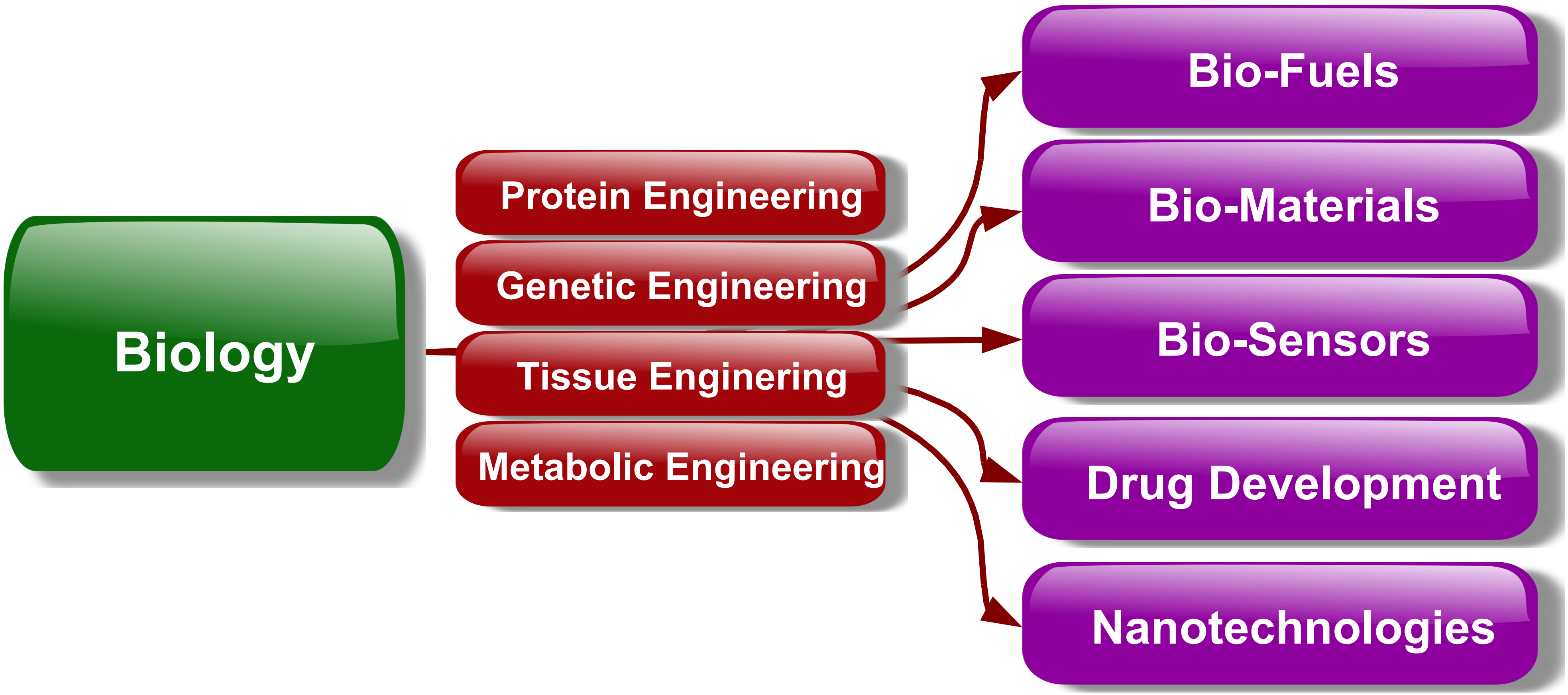
**Abstraction** | **Standardisation** | **Quality Control**

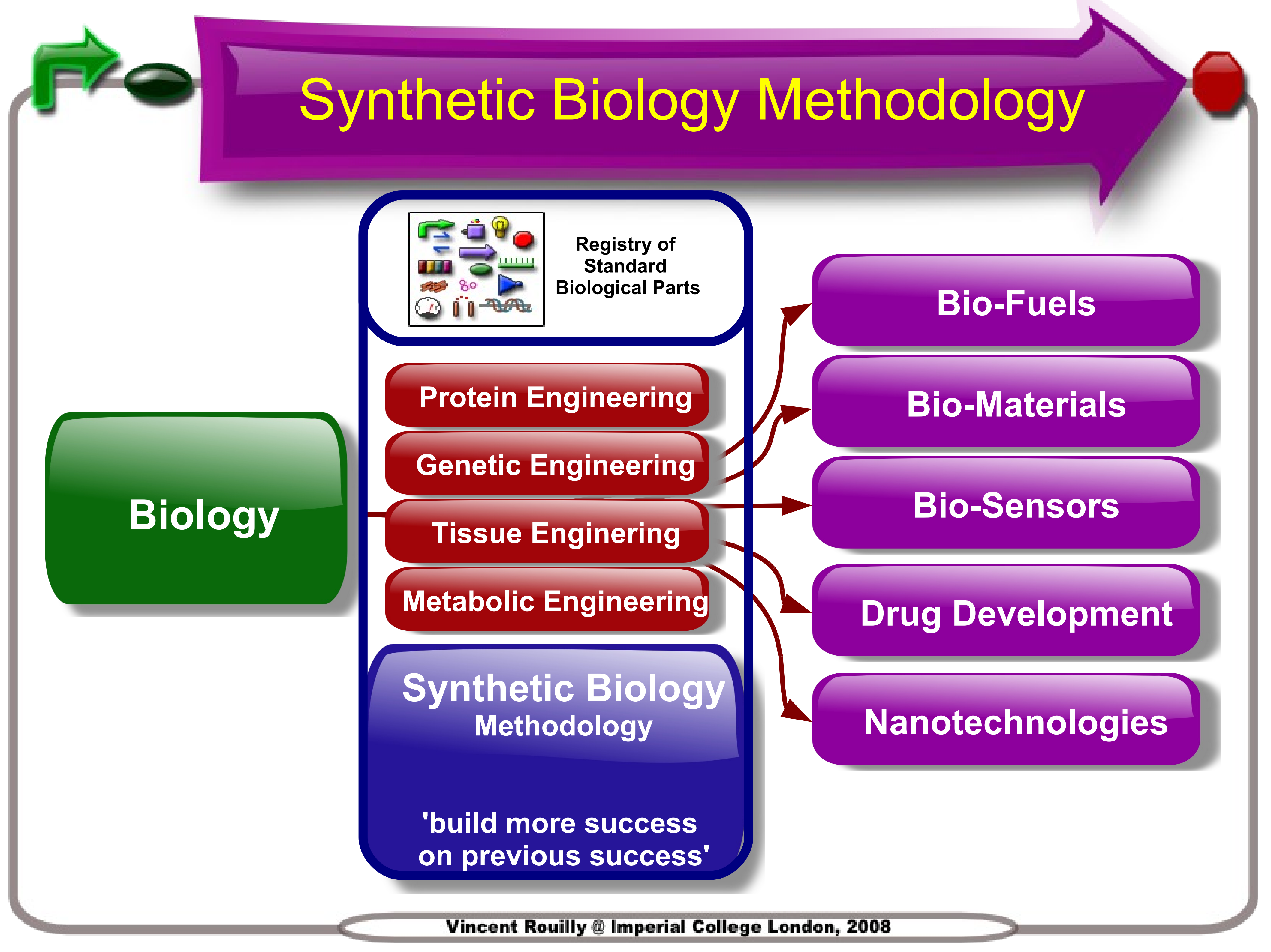


**Registry of Standard Biological Parts**

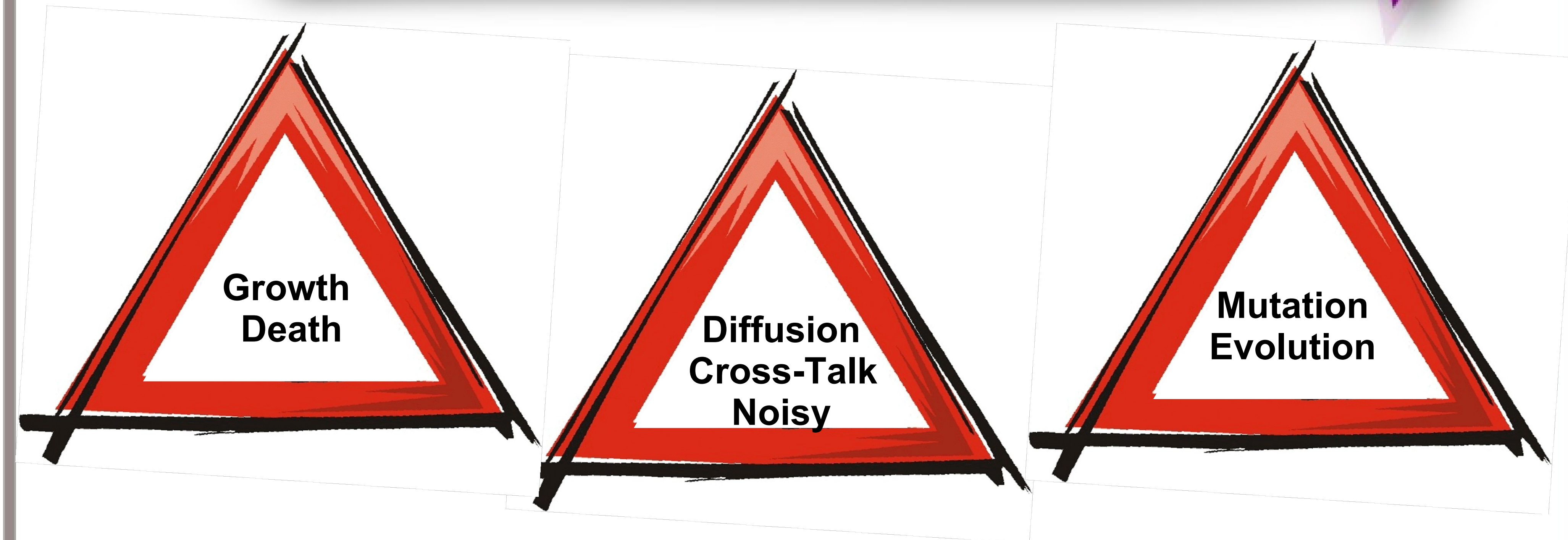
# Synthetic Biology Methodology





Synthetic Biology Methodology
Registry of Standard Biological Parts
Biology
Protein Engineering
Genetic Engineering
Tissue Enginering
Metabolic Engineering
Synthetic Biology
Methodology
'build more success on previous success'
Bio-Fuels
Bio-Materials
Bio-Sensors
Drug Development
Nanotechnologies
Vincent Rouilly @ Imperial College London, 2008

# But ....Engineering Challenges Ahead




**“What I cannot create, I do not understand.”**

**Richard Feynman (1918-1988)**

inspired by Austin Che's presentation

# Ethics and Society

**What will be the impact of**

**making biology easier to engineer ?**

from Drew Endy's talk, Tianjin 2007

# Ethics and Society

**What will be the impact of making biology easier to engineer ?**

- **More People**
- **More Powerful DNA Programs**
- **Faster Development**

from Drew Endy's talk, Tianjin 2007

# Ethics and Society

## Resulting Issues

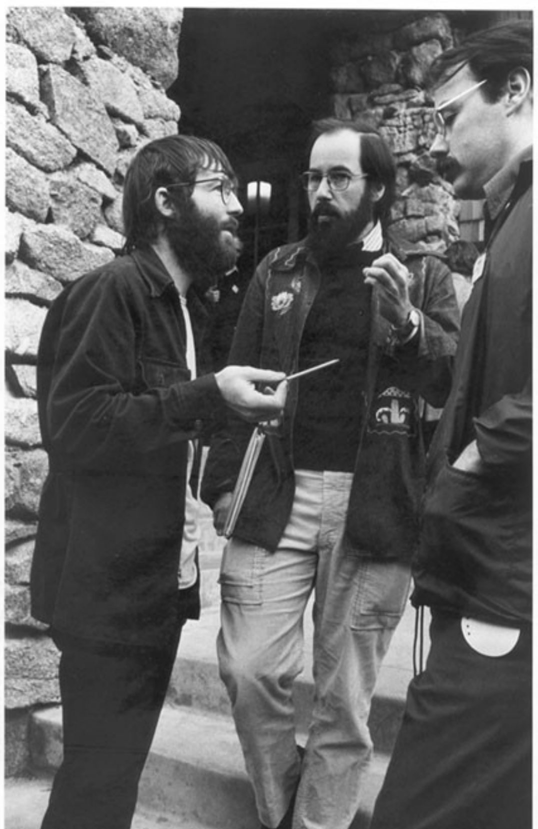
- Bio Safety
- Bio Security
- Ownership, Sharing, Innovation
- Ethics
- Community

from Drew Endy's talk, Tianjin 2007

# Ethics and Society

## Asilomar (1975)

Recombinant DNA conference



## What has changed ?

1. Databases populated with sequence information.
2. The Internet
3. Early improvements in automated DNA construction technology.
4. Overnight shipping.
5. Expanded concern re: active misapplication of biotech.

from Drew Endy's talk, Tianjin 2007

# Ethics and Society

Revitalise knowledge of biological safety

Avoid re-militarisation of biological technologies

Regardless, expect that technology will be misapplied. Prepare.

Develop an ownership & sharing framework that maximizes innovation and equity.

Build a community who can lead development of a constructive culture in Biological Engineering.

from Drew Endy's talk, Tianjin 2007

# Synthetic Biology Community

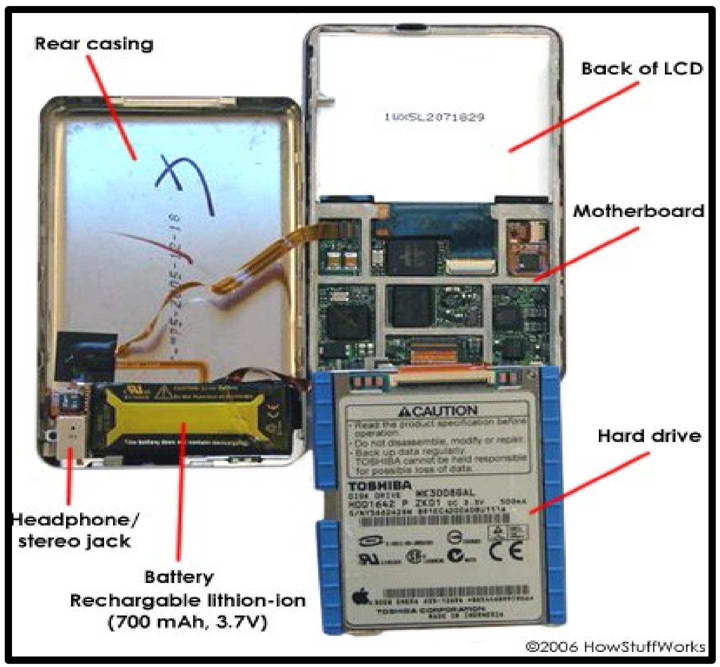
**You are now part of it !!!**

**Engage ... Challenge ... Contribute**

# References

> Drew Endy's Talks (on OWW)
> Austin Che Presentations
> OpenWetWare Folks
> iGEM Competition
> BioBricks Foundation

# Example: iPod


**Features:**

**Audio / Video / Photos**
**External hard drive**
**Calendar / Contacts**
**Games**
**Car Integration**