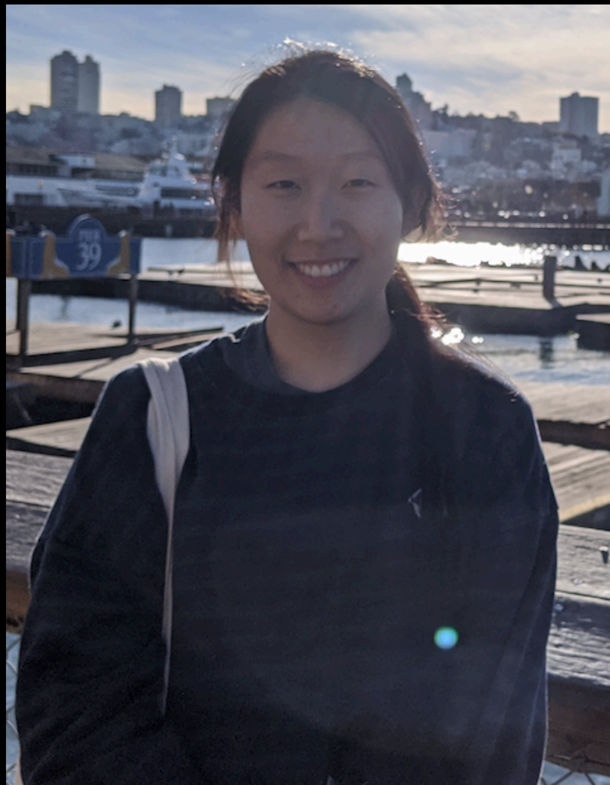
Introduction to Bioengineering
BIOE/ENGR.80
Stanford University

Spring 2020 Class Slides

Day 1
6 April 2020



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Imagine a bioengineer…

1. Draw a sketch of your bioengineer

2. Write down three words to describe your bioengineer

Imagine a bioengineer…

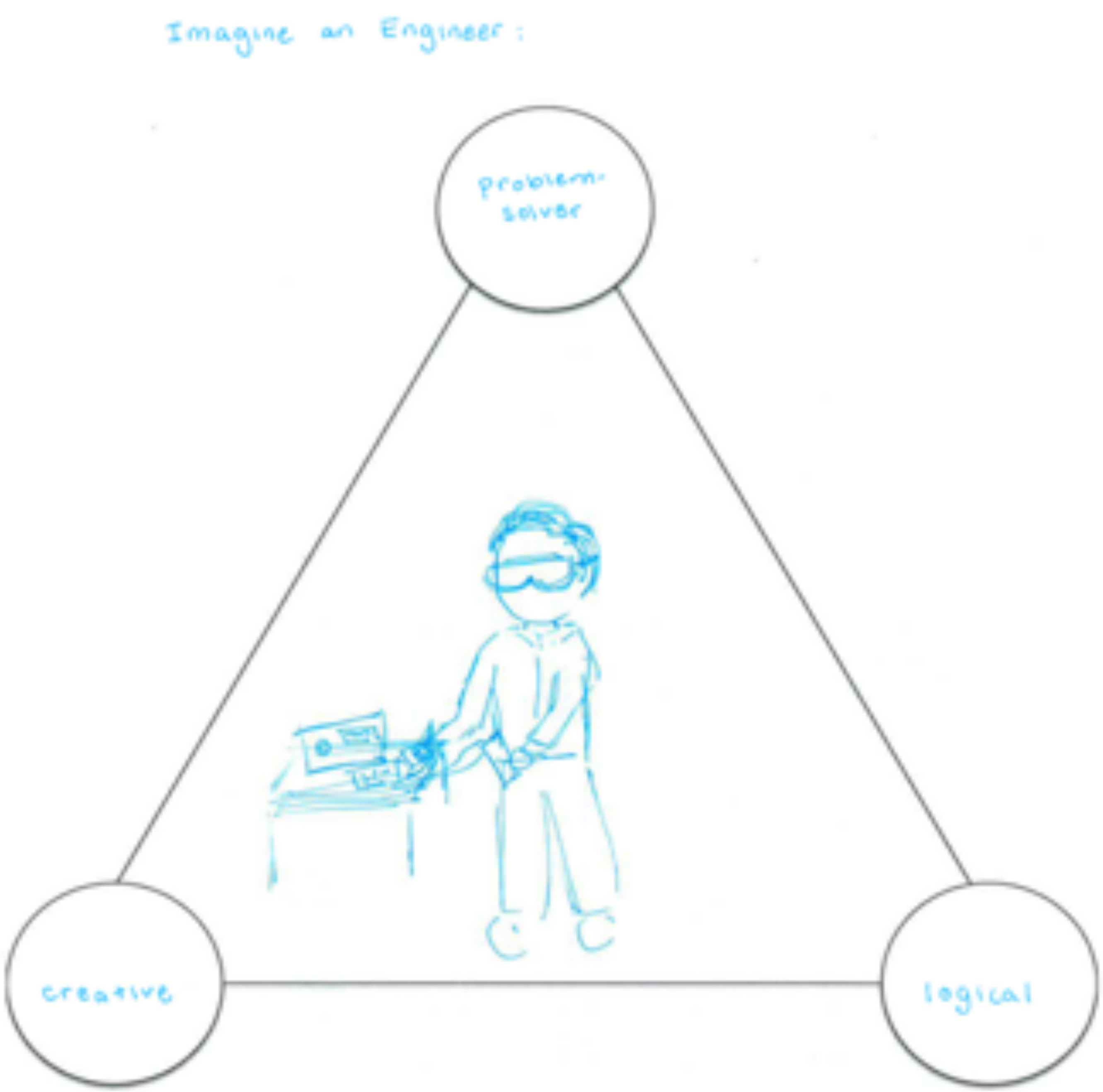
3. Find a neighbor, pair up.

4. Compare your bioengineers.

5. Note what is the same or different.

6. On a scale of 0 to 100
   how different or alike are your bioengineers?

Imagine a bioengineer…



Start of Quarter Self-Assessment

Range 0 = I don’t know what these words means – zero or near zero knowledge
1 = Basic understanding / ability - words are familiar
2 = I have done this in class, problem sets, or activities
3 = I can confidently and independently accomplish this goal
4 = I can help other learners / can fully explain
5 = I can improve the approach (method) / can do better

What is our class about?

Students successfully completing BIOE/ENGR.80 will have a working understanding for how to approach the systematic engineering of living systems to benefit all people and the planet.

Our main goals for the quarter are:

(1) to help you learn ways of thinking about engineering living matter,

(2) for you to become more capable of learning and explaining bioengineering to yourself and others,

(3) for you to be capable of leading discussions of the broader ramifications of engineering the living world.

(4) what do you wish to make true re: bioengr. by 2030?

Grading

The course is designed to operate on a S/NC basis. To earn a S grade a student must satisfy the following two conditions:

(1) Earn an average grade of 70% or above on the PSETS.
(2) Earn a cumulative grade of 70% or above on the Final Project (team-based).

Please note your lowest PSET grade will be dropped from your PSET average.

Please also note that we will offer quizzes throughout the quarter that will accrue points. You can apply your cumulative quiz points to reduce the threshold for (1) or (2) to as low as 60%, given sufficient quiz points.

Because of our S/NC grading basis please know that your teaching team is expecting and looking forward to writing very specific and detailed letters of reference, if and as useful to you.

Date	**Topic**
6 April	Why engineer biology?
8 April	What makes living matter unique?
10 April	How to read a bioengineering research paper
13 April	People health (what do people need of bioengineers?)
15 April	Planet health (what does everything else “need”?)
17 April	Political health (what does it mean to engineer biology at social scales)
20 April	Activity – Tools for seeing biology (Foldscope)
22 April	Analysis and design of molecules
24 April	Analysis and design a genetic systems

27 April	Engineering abstraction in living matter – synthetic genetic logic
29 April	Engineering abstraction in living matter – generic system architecture
1 May	Team Project – Framestorm/brainstorm plus teams rule(s)
4 May	DNA synthesis past, present, and future
6 May	Interconvertibility of genetic matter and information
8 May	Team Project – Story spine plus project priorities
11 May	Molecular diffusion and spontaneous behaviors
13 May	Activity – Dancing droplets
15 May	Programming morphogenesis (could you grow an arm?)

18 May	Team Project – Future thinking
20 May	Evolution as an algorithm
22 May	Evolution as a service
25 May	No class
27 May	Putting it all together – engineering with, of, & for biology
29 May	Team Project – Working session
1 June	Bioengineering futures related to planet health
3 June	Bioengineering futures related to human health
5 June	Team Project – Working session
8 June	Bioengineering futures related to political health
10 June	Closing discussion and charge

#include <domestication.h>

watermelon


eggplant


carrot


banana

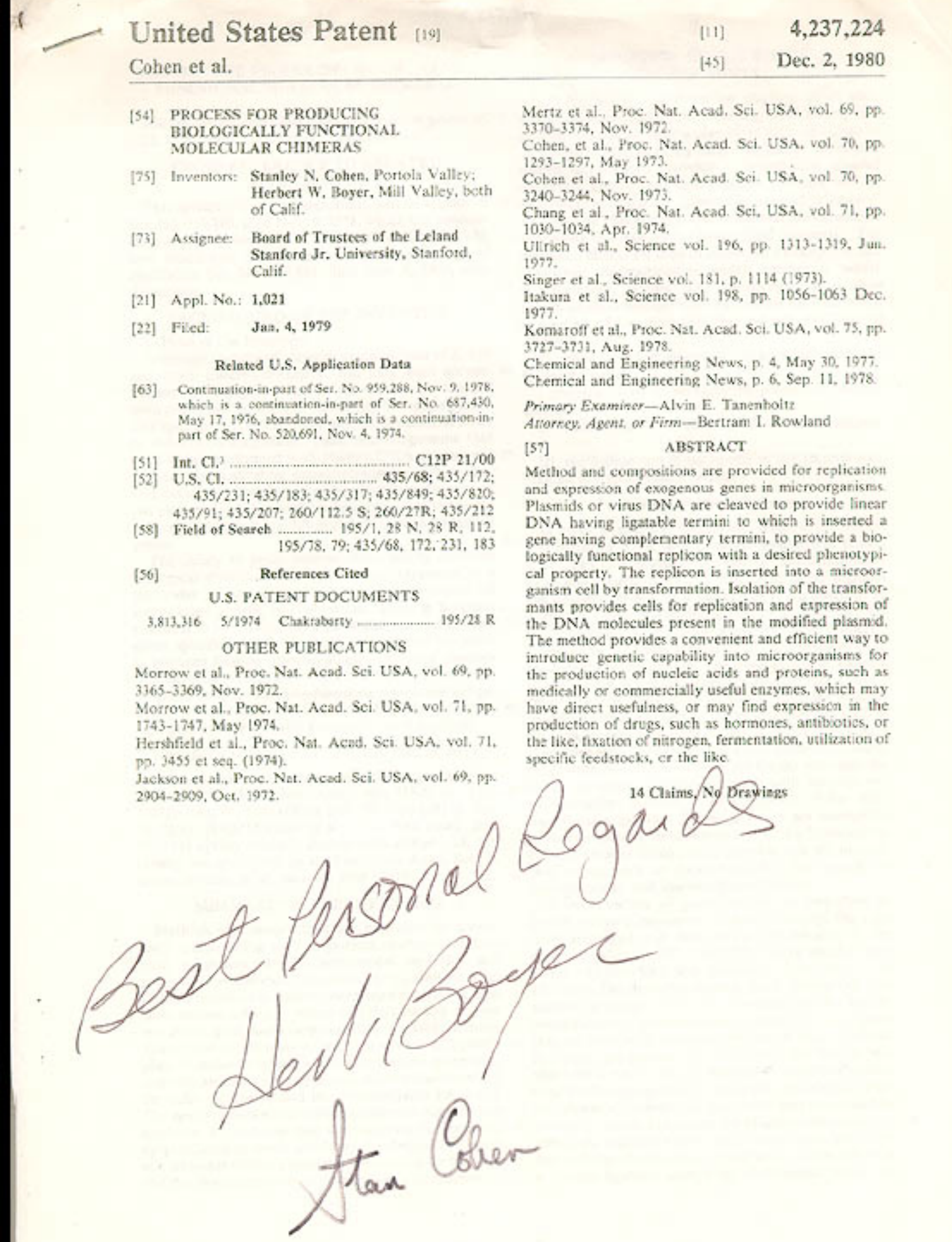

corn


broccoli

#include <breeding.h>

```
#include <landuse.h>
```

#include <geneticengr.h>



United States Patent [19] [11] 4,237,224

Cohen et al. [45] Dec. 2, 1980

[54] PROCESS FOR PRODUCING BIOLOGICALLY FUNCTIONAL MOLECULAR CHIMERAS

[75] Inventors: Stanley N. Cohen, Portola Valley; Herbert W. Boyer, Mill Valley, both of Calif.

[73] Assignee: Board of Trustees of the Leland Stanford Jr. University, Stanford, Calif.

[21] Appl. No.: 1,021

[22] Filed: Jan. 4, 1979

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 959,288, Nov. 9, 1978, which is a continuation-in-part of Ser. No. 687,430, May 17, 1976, abandoned, which is a continuation-in-part of Ser. No. 520,691, Nov. 4, 1974.

[51] Int. Cl.[3] C12P 21/00

[52] U.S. Cl. .... 435/68; 435/172; 435/231; 435/183; 435/317; 435/849; 435/820; 435/91; 435/207; 260/112.5 S; 260/27R; 435/212

[58] Field of Search .... 195/1, 28 N, 28 R, 112, 195/78, 79; 435/68, 172, 231, 183

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3,813,316 5/1974 Chakrabarty .... 195/28 R

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Chemical and Engineering News, p. 4, May 30, 1977.
Chemical and Engineering News, p. 6, Sep. 11, 1978.

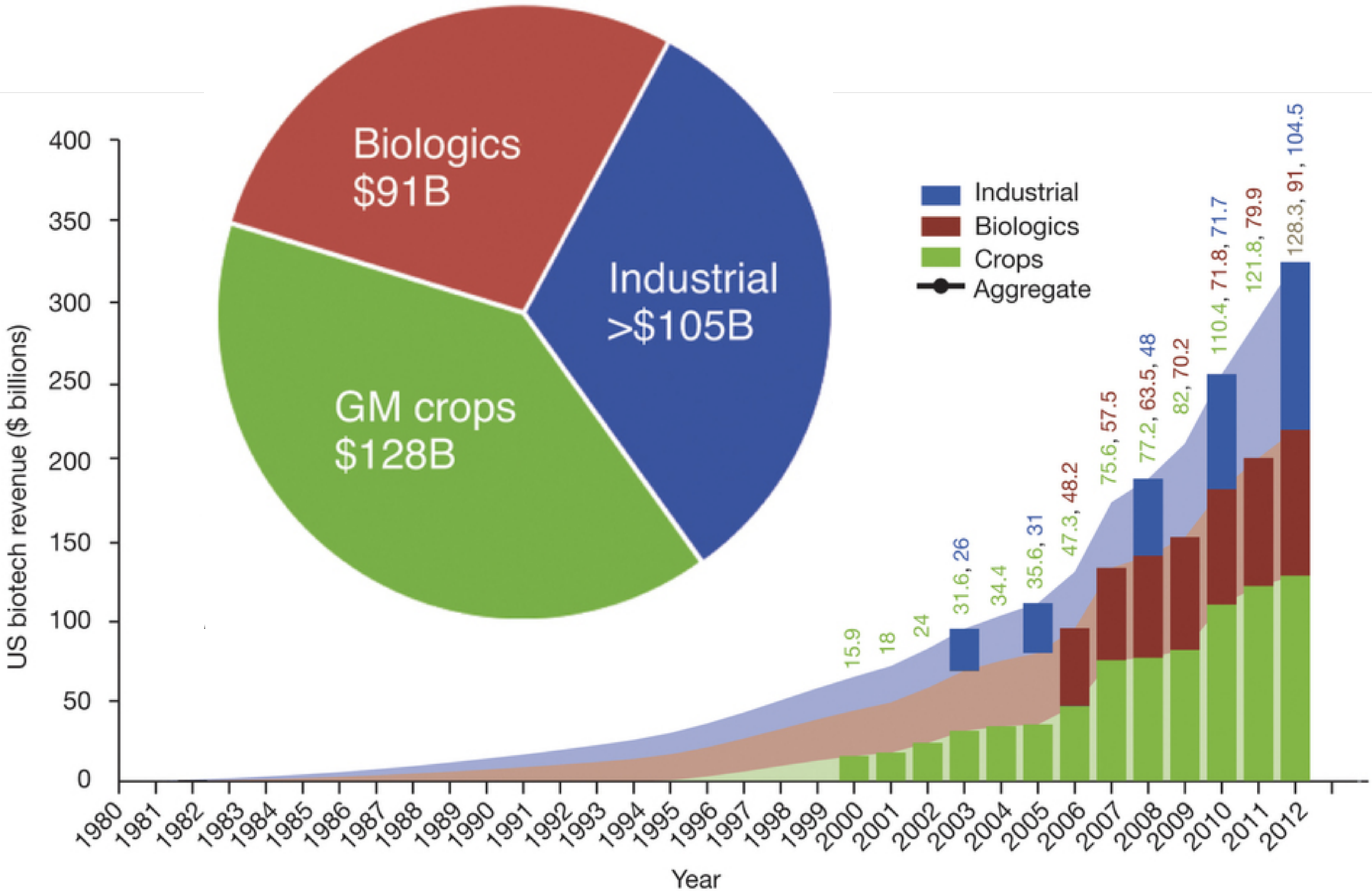
Primary Examiner—Alvin E. Tanenholtz
Attorney, Agent, or Firm—Bertram I. Rowland

[57] ABSTRACT

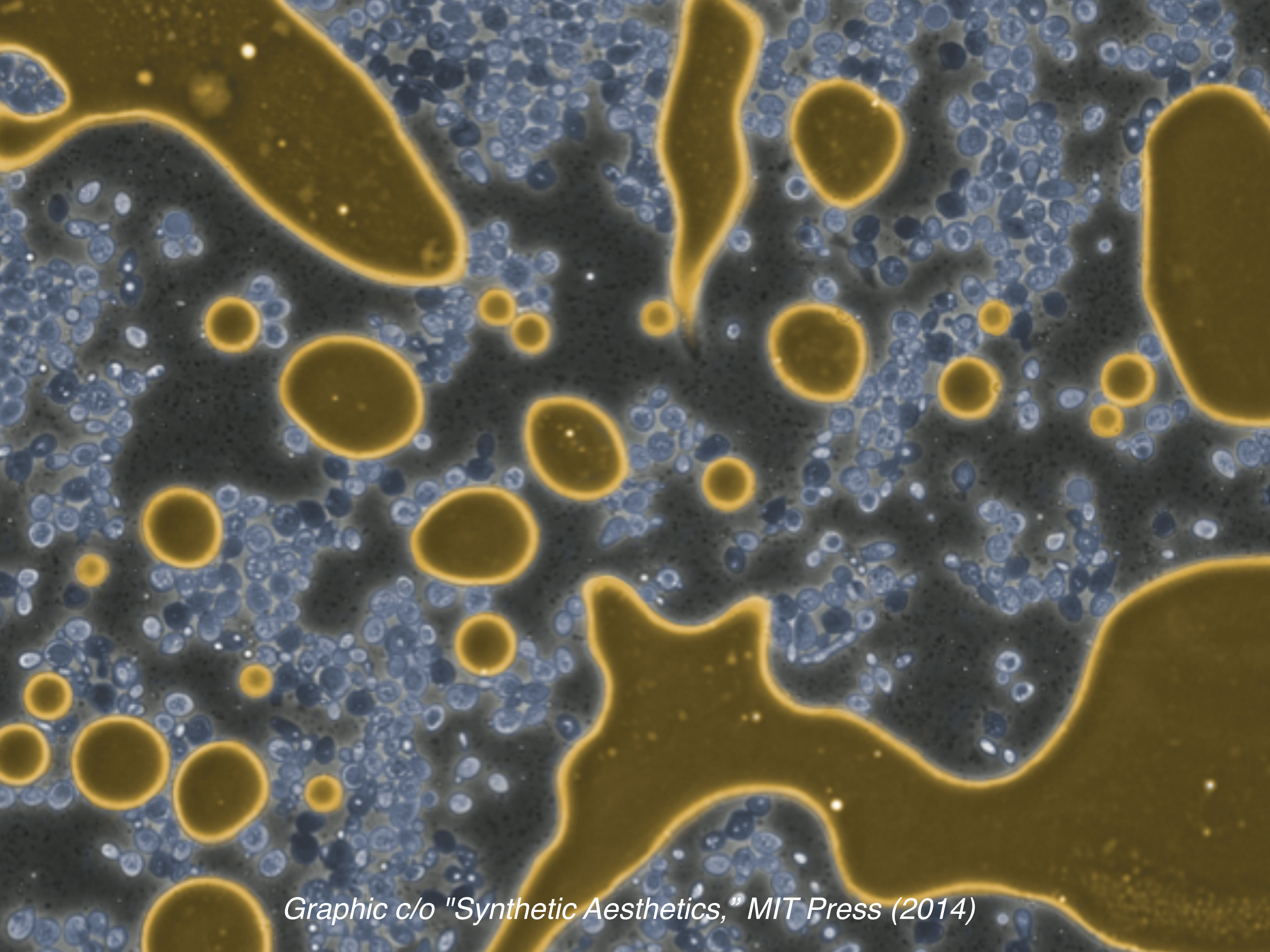
Method and compositions are provided for replication and expression of exogenous genes in microorganisms. Plasmids or virus DNA are cleaved to provide linear DNA having ligatable termini to which is inserted a gene having complementary termini, to provide a biologically functional replicon with a desired phenotypical property. The replicon is inserted into a microorganism cell by transformation. Isolation of the transformants provides cells for replication and expression of the DNA molecules present in the modified plasmid. The method provides a convenient and efficient way to introduce genetic capability into microorganisms for the production of nucleic acids and proteins, such as medically or commercially useful enzymes, which may have direct usefulness, or may find expression in the production of drugs, such as hormones, antibiotics, or the like, fixation of nitrogen, fermentation, utilization of specific feedstocks, or the like.

14 Claims, No Drawings

Genetically Engineered U.S. Domestic Product (2012)



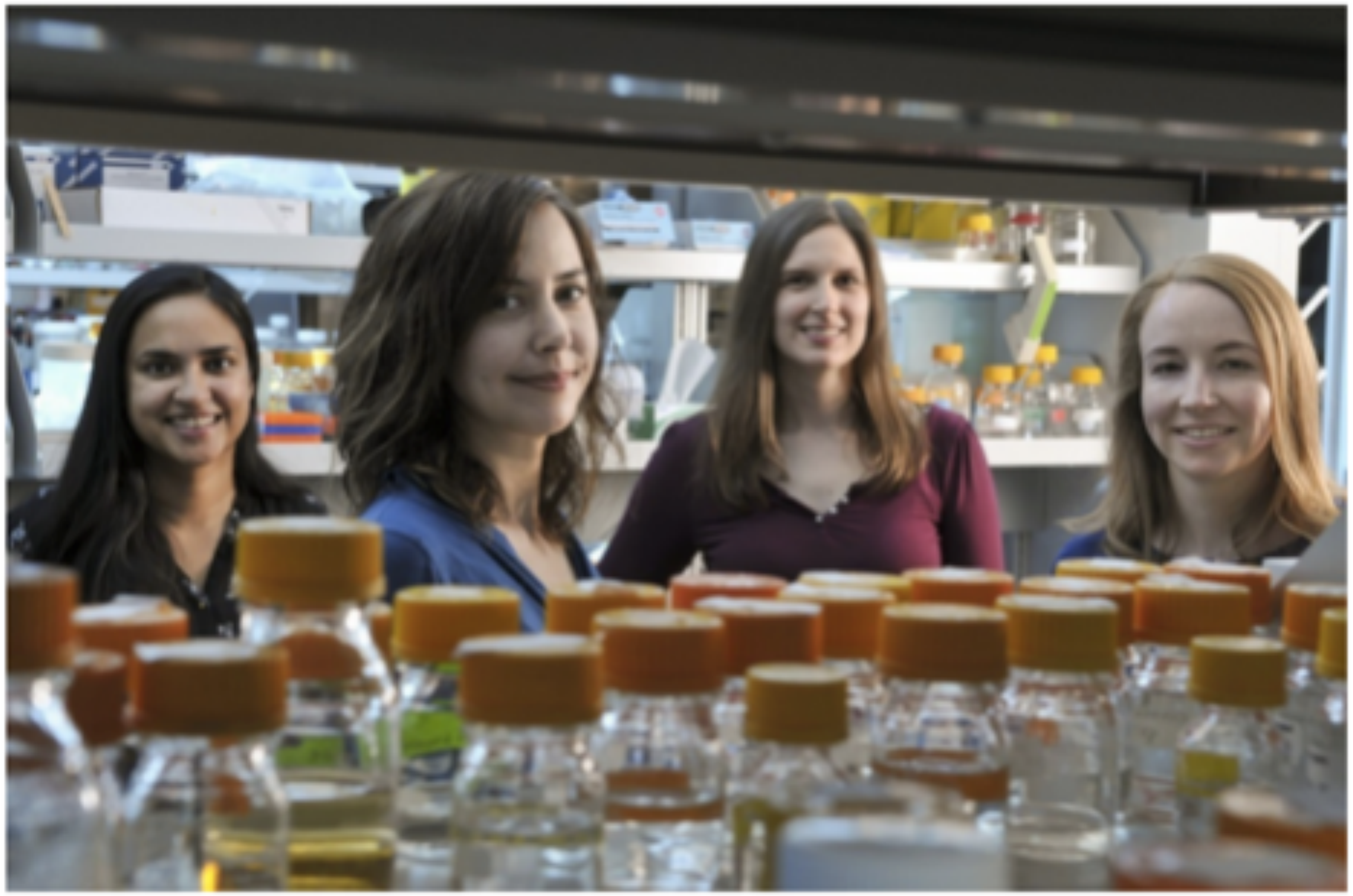
http://www.nature.com/nbt/journal/v34/n3/abs/nbt.3491.html


Graphic c/o "Synthetic Aesthetics," MIT Press (2014)

The Washington Post

Scientists engineer yeast to turn sugar into hydrocodone

By Rachel Feltman August 13 Follow @rachelfeltman



Now, for the first time, researchers at Stanford University have done it from start to finish. In a paper published Thursday in Science, they report the successful synthesis of hydrocodone from sugar, thanks to genetically engineered yeast.

ANTHEIA

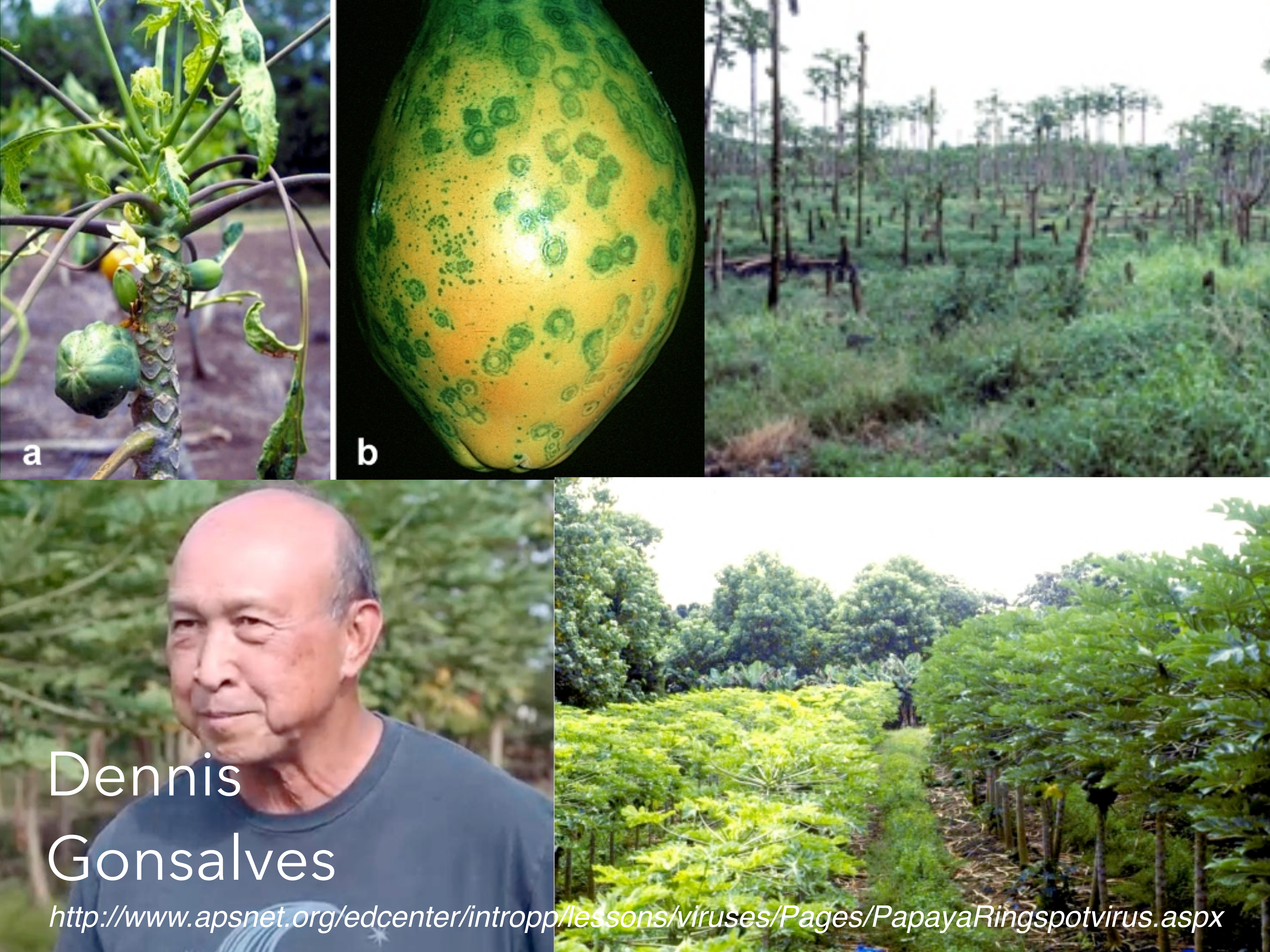
OUR TEAM CONTACT US

OUR MISSION IS TO MAKE AND FAIRLY PROVIDE MEDICINES TO ALL WHO NEED THEM

Stanford News, 08-13-15

STANFORD RESEARCHERS GENETICALLY ENGINEER YEAST TO PRODUCE OPIOIDS

It typically takes a year to produce hydrocodone from plants, but Christina Smolke and colleagues have genetically modified yeast to make it in just a few days. The technique could improve access to medicines in impoverished nations, and later be used to develop treatments for other diseases.



Dennis Gonsalves

http://www.apsnet.org/edcenter/intropp/lessons/viruses/Pages/PapayaRingspotvirus.aspx http://soefuture.stanford.edu/impact

Stanford | ENGINEERING
FUTURE

How good can we get at engineering living matter?

Pushing the limits of engineered living systems

We can now foresee achieving exponential improvements in our capacity to engineer living systems and thereby more powerfully harnessing life's intrinsic capacity for organizing atoms. A greatly expanded capacity to engineer living matter would allow us to realize precision manufacturing on a global scale, using naturally distributed platforms that operate under normal environmental conditions. Such capacities could be used to:

- Remake our civilization's supply chains by enabling local and sustainable manufacture of high-value products.
- Open new frontiers in medicine wherein engineered cells sense, diagnose, prevent and treat diseases in place.

“Enough is known already of the diverse applications of computing for us to recognize the birth of a coherent body of technique, which I call computer science...Whether computers are used for engineering design, medical data processing, composing music, or other purposes, the structure of computing is much the same.

— George Forsythe, 1961

“Enough is known already of the diverse applications of biology for us to recognize the birth of a coherent body of technique, which we call bioengineering… Whether living matter is used for manufacturing, medicine, abiotic data storage, art, or other purposes, the structure of engineering life is much the same.

— Endy & Liphardt, 2017


1
DuPont INSIGHT SERIES
DISCUSSION ON SYNTHETIC BIOLOGY
MAY 14-15 2014 PALO ALTO CA
This is a SNOWFLAKE on the TIP of the ICEBERG!
POLICY...
Science...
ethics...
TECHNOLOGY...
MARKETS...
religion...
DuPont is a SCIENCE COMPANY!
What are the ISSUES?
What is our POSITION?
What are the OPPORTUNITIES?
LISTEN...
LEARN...
ENGAGE...
CONTRIBUTE...
ADDRESS intractable problems...
Bring SOLUTIONS in a RESPONSIBLE way...
DISCOVER...
LEVERAGE...
INQUIRE...
UNDERSTAND...
UNDERSTANDING COMPLEXITY!
How do HUMANS INTERACT with the natural WORLD?
How do we get INFORMED and AWARE?
How do we DEVELOP a COMMON SHARED UNDERSTANDING?
How do we EDUCATE each other?
THIS IS ONE OF THE BIGGEST ISSUES OF OUR TIME!
We aren't seeking CONSENSUS!
We may not even need a DEFINITION...
...but are we talking about the SAME THING?
HOW
WHAT
WHERE
WHY
-IMPACT?
-RISK?
WHAT IS IN THE DEFINITION and NOT IN THE DEFINITION BOTH matter!
Do we NEED to DEFINE this?
How does it HELP US?
daTa
CREATIVITY
Biodiversity
CONSERVATION
Social issues
SYSTEMS
Ethics
ENGINEERING
SYNTHESIS
analysis
WHAT'S THE PROOF?!
DUPONT
Synthetic Biology Roundtable
14-15 May 2014 • Palo Alto, CA USA
dpict.
Images by Anthony Weeks
www.dpict.info

Food

Energy

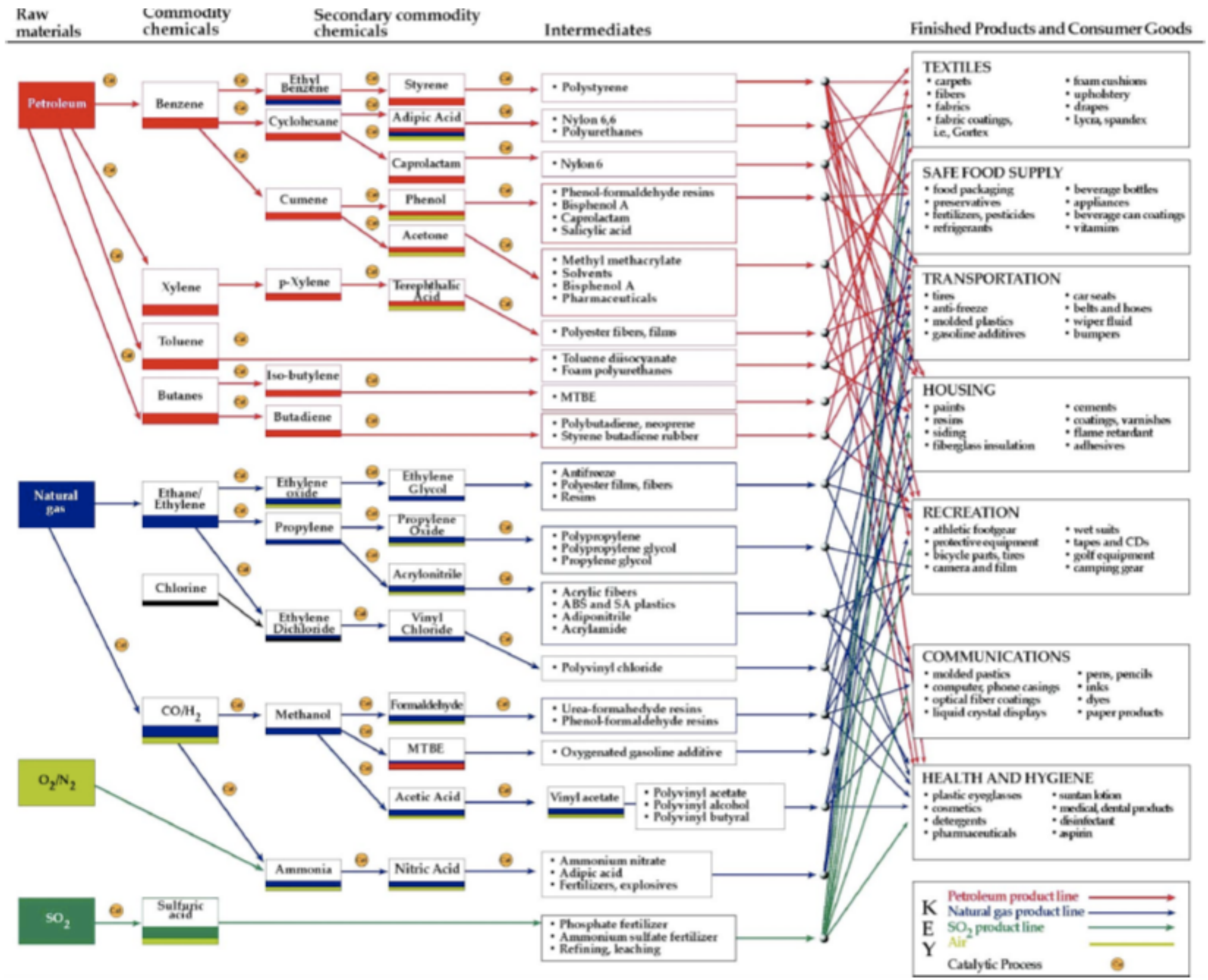
Environment

Agriculture

Health

Chemicals & Materials

Security



Food

Energy

Environment

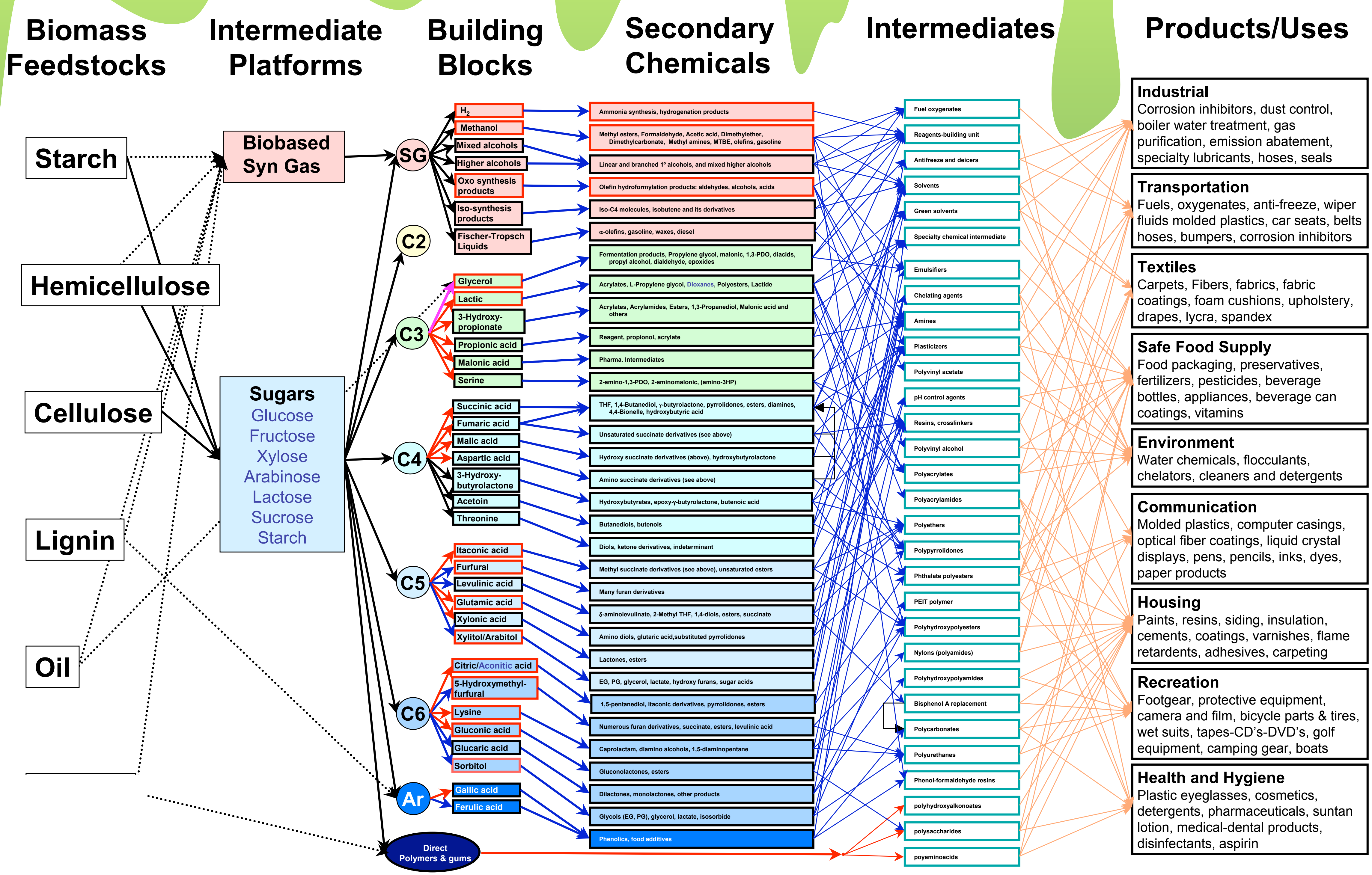
Agriculture

Health

Chemicals & Materials

Security

2004 DOE report lists 120 highvalue chemicals for biomanufacturing



Graphic c/o "Synthetic Aesthetics," MIT Press (2014)

Photo by Roger Lancaster (http://www.flickr.com/photos/rogeral/5813079061/); educational fair use


CALIFORNIA GROWN
ORGANIC MUSHROOMS
CALIFORNIA GROWN
ORGANIC MUSHROOMS
PRODUCT OF U.S.A.

We turn mycelium and agricultural byproducts into leather.

Photovoltaic ROE >> 1

Renewable and Sustainable Energy Reviews 47 (2015) 133–141

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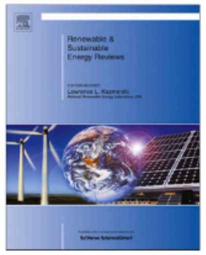

Energy payback time (EPBT) and energy return on energy invested (EROI) of solar photovoltaic systems: A systematic review and meta-analysis

CrossMark

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Energy return on energy invested
Embedded energy

ABSTRACT

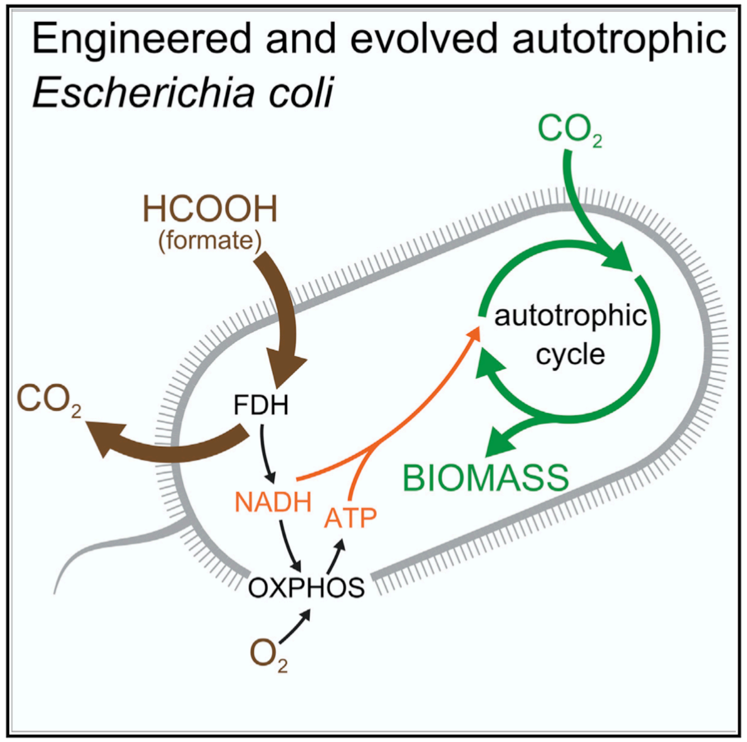
There is a fast growing interest in better understanding the energy performance of PV technologies as evidenced by a large number of recent studies published on this topic. The goal of this study was to do a systematic review and a meta-analysis of the embedded energy, energy payback time (EPBT), and energy return on energy invested (EROI) metrics for the crystalline Si and thin film PV technologies published in 2000–2013. A total of 232 references were collected of which 11 and 23 passed our screening for EPBT/EROI and embedded energy analysis, respectively. Several parameters were harmonized to the following values: Performance ratio (0.75), system lifetime (30 years), insolation (1700 kWh m^{-2} yr^{-1}), module efficiency (13.0% mono-Si; 12.3% poly-Si; 6.3% a:Si; 10.9% CdTe; 11.5% CIGS). The embedded energy had a more than 10-fold variation due to the variation in BOS embedded energy, geographical location and LCA data sources. The harmonization narrowed the range of the published EPBT values. The mean harmonized EPBT varied from 1.0 to 4.1 years; from lowest to highest, the module types ranked in the following order: cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), amorphous silicon (a:Si), poly-crystalline silicon (poly-Si), and mono-crystalline silicon (mono-Si). The mean harmonized EROI varied from 8.7 to 34.2. Across different types of PV, the variation in embedded energy was greater than the variation in efficiency and performance ratio suggesting that the relative ranking of the EPBT of different PV technology today and in the future depends primarily on their embedded energy and not their efficiency.

Transitioning to electricity abundant civilization

Electro-fermentation...

Conversion of *Escherichia coli* to Generate All Biomass Carbon from CO_2

Graphical Abstract



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In Brief

Metabolic rewiring and directed evolution led to the emergence of *E. coli* clones that use CO_2 as their sole carbon source, while formate is oxidized to provide all the reducing power and energy demands.

Gleizer et al., 2019, Cell *179*, 1255–1263
November 27, 2019 © 2019 The Authors. Published by Elsevier Inc.
https://doi.org/10.1016/j.cell.2019.11.009

Original Paper | Published: 13 September 2008

Electro-reduction of carbon dioxide to formate on lead electrode in aqueous medium

B. Innocent, D. Liaigre, D. Pasquier, F. Ropital, J.-M. Léger & K. B. Kokoh

Journal of Applied Electrochemistry **39**, Article number: 227 (2009) | Cite this article

Abstract

The electrochemical reduction of carbon dioxide on a lead electrode was studied in aqueous medium. Preliminary investigations carried out by cyclic voltammetry were used to determine the optimized conditions of electrolysis. They revealed that the CO_2 reduction process was enhanced at a pH value of 8.6 for the cathodic solution i.e. when the predominant form of CO_2 was hydrogenocarbonate ion. Long-term electrolysis was carried out using both potentiometry and amperometry methods in a filter-press cell in which the two compartments were separated by a cation-exchange membrane (Nafion® 423). Formate was detected and quantified by chromatography as the exclusive organic compound produced with a high Faradaic yield (from 65% to 90%). This study also revealed that the operating temperature played a key role in the hydrogenation reaction of carbon dioxide into formate in aqueous medium.

~1 kWh electricity = ~ 1 gram new biomass

~$0.11 = ~ 1 course of antibiotics

Q. How will this box change the world?

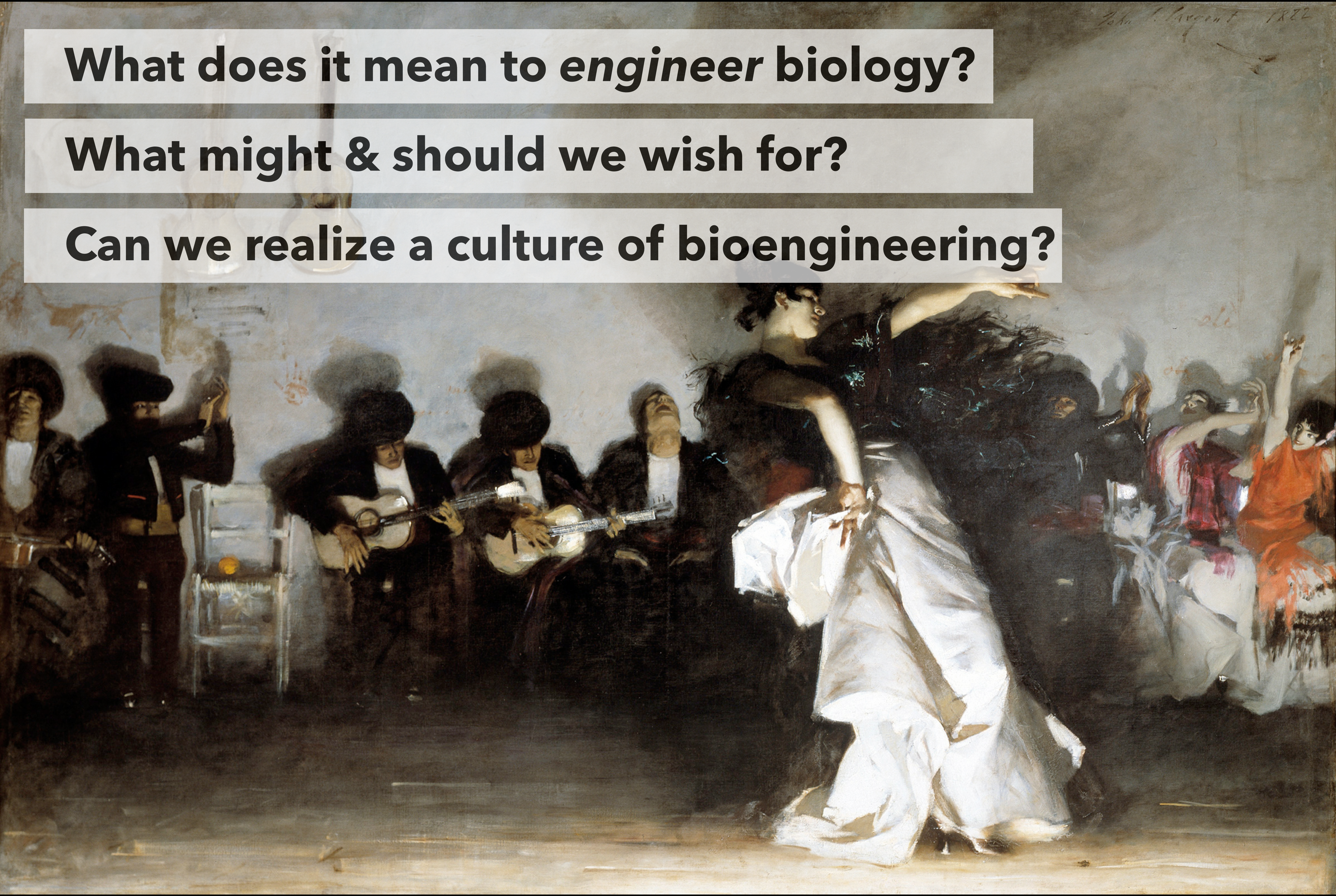
Q. What will the "PB" + the "bionet" lead to?

A. "design anywhere, grow everywhere"

What does it mean to *engineer* biology?

What might & should we wish for?

Can we realize a culture of bioengineering?



https://en.wikipedia.org/wiki/El_Jaleo

"The modern field of conservation was born as a crisis discipline and it really was focused on trying to stop extinction.

So what does conversation want? What it wants is to conserve nature. Particular biodiversity and species and ecosystems with less emphasis on the genetic component.

It is based on a set of foundational values that focus on the natural and the wilderness.

It wants a world that doesn't change except by its own agency.

It embraces change but natural change." — Kent Redford

https://vimeo.com/225308429

https://secure3.convio.net/wcs/pdf/Synthetic_Biology_and_Conservation_Framing_Paper.pdf

What is our telos?

Biology is already many places

~90 terawatts via photosynthesis*

Reproducing, growing, & healing materials

Massively functional

Living ramifications

*electrobiosynthesis will remove this cap

Enable humanity to provide for itself

Stabilize & recover natural biodiversity

Take infectious & other diseases off the table

Enable a culture of citizenship

Understand life via building

The living bridges of Cherrapunji, India are made from the roots of the Ficus elastica tree. (http://rootbridges.blogspot.com/)