

SYNTHETIC BIOLOGY: ASSEMBLING BIOLOGICAL ORGANISMS AND SYSTEMS

when everything is
programmable:
LIFE IN A COMPUTATIONAL AGE

At the intersection of the biosciences and engineering, researchers are learning to design and build living systems that may not exist in nature. Synthetic biology treats natural processes as a code, a set of instructions guiding the creation of living organisms, and seeks to manipulate this code to genetically reengineer existing life and create new life forms with purpose. Organisms with extraordinary capabilities will become possible, such as bugs that glow red in the presence of certain environmental contaminants and digest the toxins, biosynthetic solar cells that mimic a plant's light-harvesting systems, and bacteria that convert waste paper or biomass into octane for fuel.

OPEN-SOURCE BIOLOGY

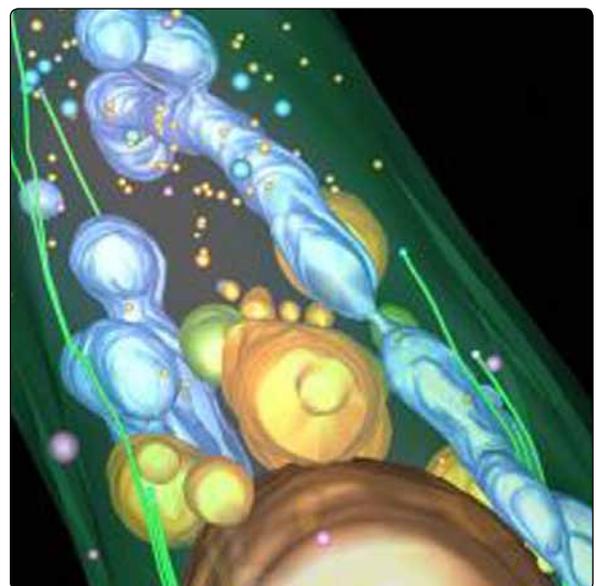
As synthetic biology develops into an industry, it will embody the lessons learned from the open-source software movement. Synthetic biology's "code"—that is, the genetic components themselves—will be worth only what you can do with that code. This turns biology into an engineering science; however, the value won't be in patented genomes or organisms but rather in innovative applications, infrastructure, and methods of production.

PROGRAMMING FOR SUSTAINABILITY

Research is under way to engineer organisms that seek out various contaminants and toxins and then digest and degrade them. Bioengineers are studying how microorganisms might be used to decontaminate hazardous waste spills and nuclear disposal sites. Synthetic biology could also lead to new, sustainable fuel sources. J. Craig Venter, the biologist who famously led the commercial effort to sequence the human genome, has suggested that the carbon dioxide spewing from power plants could be converted by microbes into natural gas to power the boiler. The scientists at his company are also designing biological systems to convert sunlight directly into hydrogen through photosynthesis. Other engineered organisms will become "fuel factories," chewing up plant material and spitting out biofuel.

BIOLOGICAL MANUFACTURING

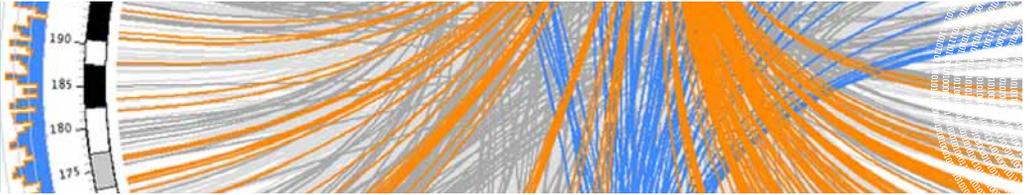
The first "killer app" for synthetic biology will likely be in manufacturing. Reprogramming the metabolic pathways of cells will transform vats of bacteria into drug production facilities. Already, University of California, Berkeley's Jay Keasling has inserted genes from multiple organisms into *E. coli* so it will spew a precursor to the anti-malaria drug artemisinin, potentially reducing the cost of a treatment from dollars to pennies. Synthetic biology will also transform the production of anti-cancer and AIDS drugs. Beyond biopharma, the same technologies could result in cleaner, more efficient, and cheaper methods to produce a variety of industrial chemicals and materials.



Synthetic yeast cell



ENABLING TECHNOLOGIES



Genomics:

Reading the book of life

Bioinformatics:

Life as data

Molecular Engineering:

Building from the bottom up

Simulation:

Modeling possibility space

Parallel Programming:

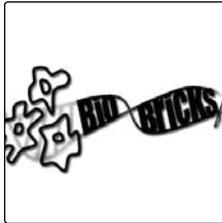
Applications for a multi-threaded world

Deep Web:

Semantic engineering of linked data

Signals:

BIOBRICKS FOUNDATION (OPEN-SOURCE BIOLOGY)



The BioBricks Foundation, a not-for-profit organization cofounded by Stanford synthetic biology pioneer Drew Endy with colleagues from MIT, Harvard, and University of California, San Francisco, aims to build an information clearinghouse of sequence information for standard DNA parts that encode basic biological functions. The idea is that these interchangeable “biobricks”—genes, proteins, and cells—can be snapped together like Tinkertoys to build living systems. The BioBricks sequence information is freely available to the public through MIT’s Registry of Standard Biological Parts.

Source: <http://bbf.openwetware.org/>

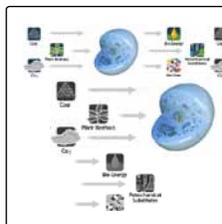
JOINT BIOENERGY INSTITUTE (PROGRAMMING FOR SUSTAINABILITY)



Supported by the U.S. Department of Energy, the Joint BioEnergy Institute has the goal of developing biofuel alternatives to fossil fuels. The JBEI is researching synthetic biology technologies to produce these liquid fuels derived from plant biomass in a sustainable and cost-effective manner. Synthetic biology pioneer Jay Keasling, University of California, Berkeley professor and director of Lawrence Berkeley National Laboratory’s Physical Biosciences Division, is the CEO of the Institute.

Source: <http://jbei.org/technologies/>

SYNTHETIC GENOMICS (BIOLOGICAL MANUFACTURING)



Synthetic Genomics, J. Craig Venter’s company, has made strides in building the first entirely artificial organism from the bottom up. From a commercial perspective, the firm is focusing on synthetic biology for energy applications, but according to its website, it imagines a future where its science could be used to produce “a variety of products, from synthetically derived vaccines to prevent human diseases to efficient cost-effective ways to create clean drinking water.”

Source: <http://www.syntheticgenomics.com/>

What difference does this make?

Biology will become an engineering discipline, albeit one fraught with controversy around the rallying cry of “Don’t mess with Mother Nature!” We may see a new kind of industrial revolution, embodying a shift from manufacturing to growing the stuff of our world.

BIOLOGY AS AN ENGINEERING DISCIPLINE

For 3.6 billion years, evolution has governed the biology of this planet. Molecular biologists can now shift bits of DNA from one organism to another, but the parts they play with are limited to what nature provides. While biomimicry gave designers inspiration to develop new materials, devices, and technologies inspired by nature, synthetic biology promises the ability to design nature itself. The traditional engineering principles of modularity, abstraction, and standardization still apply.

EXTREME GREENING OF DESIGN AND MANUFACTURING

Reprogramming existing organisms and making entirely new ones could transform the way products are designed, made, and distributed. Genetically engineered biofactories may give new meaning to the phrase “sustainable manufacturing.” Meat and produce, including newly invented varieties, may be biologically manufactured rather than bred or grown. New organisms may help clean up industrial messes, we can hope without causing new ones.

BIOLOGY AS LINGUA FRANCA OF THE TECHNOLOGY INFRASTRUCTURE

Technology infrastructure will shift from inorganic to organic across the board. On the horizon are DNA computers, genetic algorithms, and “evolved” software. Anyone connected to IT processes in an organization will learn the language of biology.

GROWING THREAT OF BIODISASTER

Synthetic biology opens the gates of what’s possible, and it could also open a Pandora’s box of biodisasters. Ideally, synthetic biology will be self-regulated without the need for government intervention. But before scientists can convince the public that the field is safe, they themselves must ensure that it is safe. Otherwise, the old adage that you shouldn’t mess with Mother Nature may ring truer than ever before.



What to do differently?

Look to nature, across disciplinary boundaries, and to university biology labs for inspiration.

IDENTIFY PROCESSES IN YOUR ORGANIZATION THAT COULD BECOME MORE BIOLOGY BASED

Look for inspiration in nature for ways to innovate around process optimization, product design, and sustainable operations. Inspiration for new materials, organizational structures, and even knowledge work can be found in nature.

REVERSE MENTOR IN A BIOLOGY LABORATORY AT A NEARBY UNIVERSITY

Identify individuals or organizations who are exploring how the field is having unexpected impact in nonobvious domains. Engage in knowledge exchanges to find surprise intersections between your organization and the biological sciences.

CULTIVATE TRANSDISCIPLINARITY

Managing an organization's manufacturing processes and information technology requires a transdisciplinary approach that will draw as much from genomics and bioinformatics as it does from industrial operations and software systems engineering.

SPONSOR A TRANSDISCIPLINARY RESEARCH PROJECT

Find a transdisciplinary research project at a university at the forefront of synthetic biology and offer to sponsor it. If possible engage in the experiments to share real world data for analysis.



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