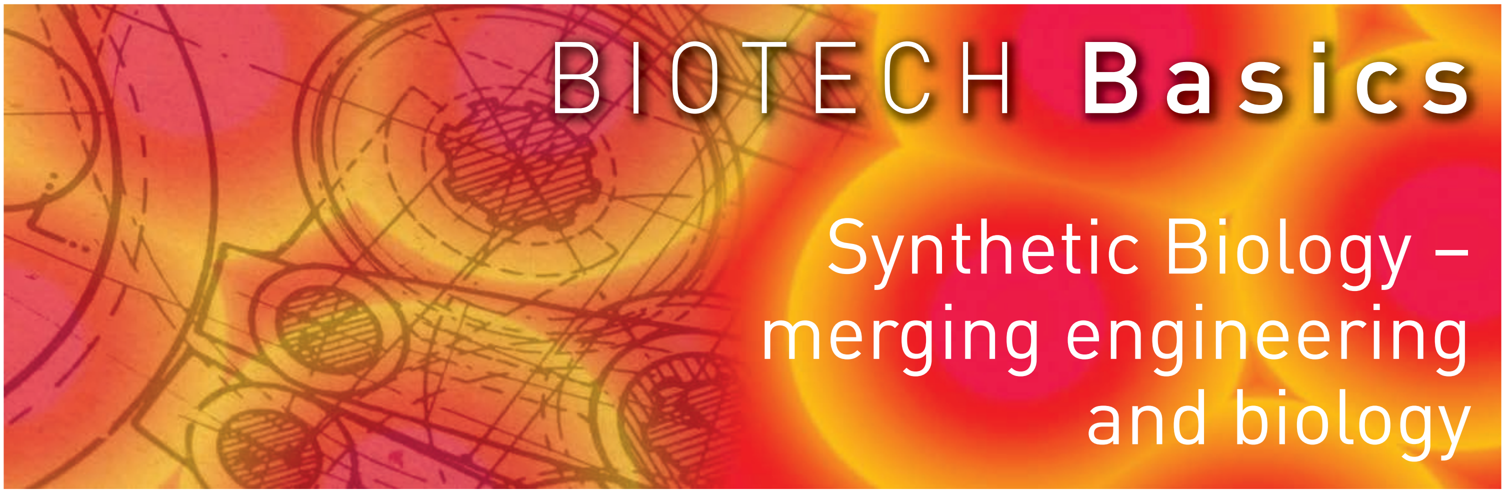


BIOTECH Basics

Synthetic Biology – merging engineering and biology

What You Need to Know

- *Synthetic biology uses engineering principles to design and create biological systems that carry out specified functions*
- *The basic building blocks are fragments of DNA.*
- *The DNA components are combined in new ways to produce more efficient products such as medicines, energy sources or environmental sensors.*
- *Synthetic biology is an emerging field with a number of technical, ethical and security issues still to be addressed.*

For more information:

www.iXpressGenes.com
iXpressGenes (iXG) is a resident associate company supporting life sciences organizations and research laboratories worldwide with all aspects of synthetic biology and genomics. iXG scientists and engineers have pioneered bio-automation solutions for gene synthesis, protein engineering, production of novel recombinant enzymes and protein crystallization.

www.jcvi.org
J. Craig Venter Institute. Click on the link for First Self-Replicating Synthetic Bacterial Cell to learn more about the synthesized Mycoplasma.

http://bbf.openwetware.org
The Registry of Standard Biological Parts provides access to the catalog of BioBrick™ parts available to the synthetic biology community.

www.raeng.org.uk/synbio
This is a recent report on synthetic biology published by the British Royal Academy of Engineering. It includes an excellent overview of the science and potential future applications.

"What do you get when you cross an engineer with a geneticist?"

While that may sound like the opening line for a joke, it's actually an emerging field of science known as synthetic biology. This area has received a lot of recent news coverage, with the announcement by an American institute that they had created the first bacterial cell with a genome designed by a computer and made entirely in the lab. This announcement quickly prompted a congressional hearing examining the implications of synthetic biology. In this edition of Biotech Basics, we'll explore the ideas behind the field, highlight some of the most recent discoveries and look at possible applications and concerns related to synthetic biology.

What is synthetic biology?

Synthetic biology seeks to apply engineering principles to biology. It has an ultimate goal of designing and building biological systems for specified tasks (e.g. drug development, material fabrication and energy production). The field is a collaborative effort between not only engineers and biologists, but also chemists and physicists.

Reviewing the basics

Living systems are composed of several basic key components that are critical for growth and replication. The function and structure of many of these components are known in great detail, thanks to our understanding of the relationship between DNA, RNA and proteins. The genetic code, contained in the DNA sequence, provides the instructions for making all the proteins needed by a cell. These instructions are converted from the DNA sequence into a temporary "working document" called RNA, which then directs the assembly of amino acids into the required protein.

BioParts, devices and systems

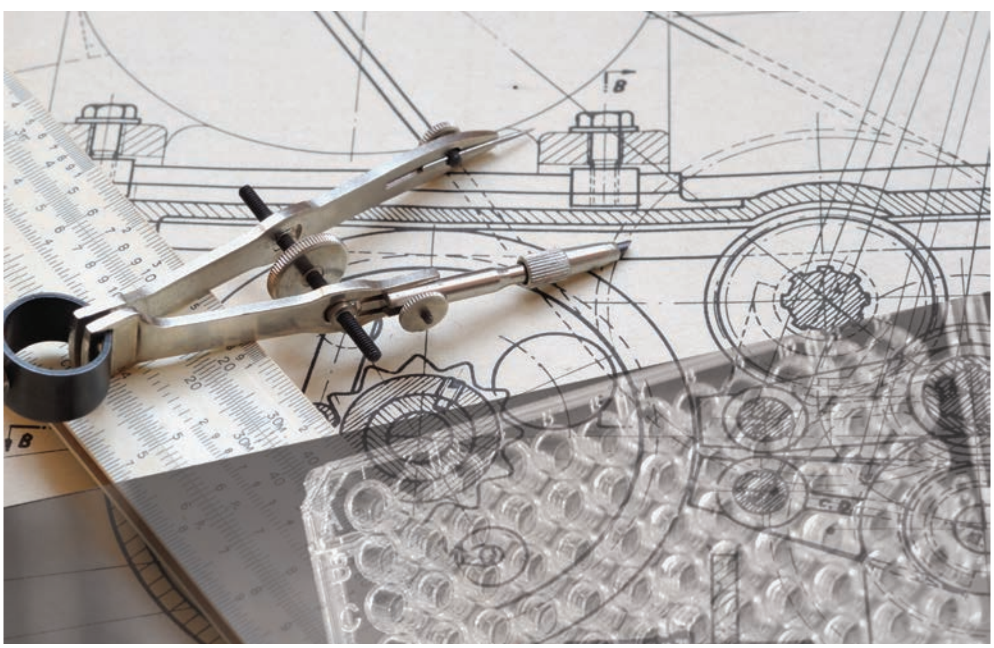
Synthetic biology aims to use engineering methods to build novel and artificial biological tools. This is done using an established engineering approach - defining the specification for a device or system and then using a set of standard parts to create a model that meets that specification. The basic building block is a biopart - a fragment of DNA with a specific function such as producing a protein or activating a "start/stop" switch. Bioparts are combined into devices that carry out a desired activity, like producing fluorescent protein under a given condition. Multiple devices can be connected into a system, which performs more complex, higher-level tasks.

Powerful computers offer in-depth modeling and simulation to predict the behavior of the part, device or system before it is assembled. The relevant DNA instructions are then artificially synthesized and inserted into a biological cell, such as bacteria. The bacterial cell is the "chassis" or vehicle that interprets the DNA instructions. If the synthesized information is read and processed correctly, then the specification and design were appropriately crafted. If not, the original design is modified, continuing the design-modeling-testing cycle. Once complete, the device or system becomes a component created from standard bioparts, rather than constructed each time from scratch.

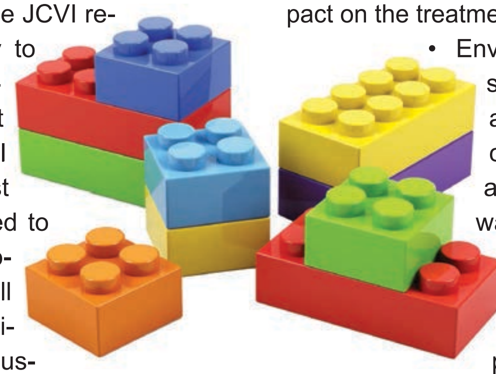
The BioBricks™ Foundation, a not-for-profit organization, uses this methodology. Developed by scientists and engineers from MIT, Harvard and UCSF, it maintains The Registry of Standard Biological Parts - a collection of several thousand open-source bioparts known as BioBricks™. For example, there are BioBricks™ that produce plastics, control cell movement, or produce odors; they can be mixed and matched to build synthetic devices and systems. Each conforms to a standard format, allowing a developer to assemble systems that can integrate into other BioBricks™-based creations, much like snapping together sets of LEGO© plastic bricks.

Synthesizing an organism from scratch

Rather than creating individual devices or systems that can be inserted into existing bacteria, researchers at the J. Craig Venter Institute (JCVI) have pursued a different approach - creating the entire bacterial genome from scratch. This team recently synthesized the 1.08 million base-pair genome from Mycoplasma mycoides, a bacteria that often infects goats, but is not dangerous to humans. The genome was created by synthesizing DNA fragments from bottles of chemicals in the laboratory, assembling fragments into an entire genome and inserting it into a host Mycoplasma cell whose own DNA was destroyed. When the host cells grew and divided, they did so under the direction of the synthesized genome.



The ultimate aim of the JCVI researchers is not simply to replicate a synthetic version of the genome, but to produce a “minimal cell” with the smallest number of genes needed to support growth and replication. The minimal cell then serves as a biological chassis, into which user-designed devices and sytems can be inserted - producing more complex organisms with useful properties.



What lies ahead?

The rise of synthetic biology has been compared to that of synthetic chemistry, a field that developed and matured during the past century as chemists learned how to synthesize compounds that previously only existed in nature. Early examples, such as dyes and medicines like aspirin, gave way to the creation of plastics, semiconductors and complex pharmaceuticals. Many supporters believe that synthetic biology has the potential to achieve equally important results, including:

- Health: The Gates Foundation is working to develop a semi-synthetic version of the anti-malarial drug artemisinin. By incorporating the necessary genetic information, the drug can be crafted inside a bacterial cell, leading to large-scale production methods. If successful, this endeavor will have a major impact on the treatment of malaria.
- Environment: Biosensors have been created which detect contaminants, such as arsenic, in the water. These biosensors may be coupled to bacterial purification processes to produce clean water for drinking and agriculture.
- Biofuels: Current methods of biofuel production make ethanol from sugars or biodiesel from vegetable oils, however these methods waste nearly 90 percent of the organic plant matter (called biomass). Synthetic biology derived biofuels are being designed to use a much higher proportion of the biomass, significantly increasing yields.

Challenges and concerns

Given that synthetic biology involves creating novel living organisms, it isn’t surprising that security, safety and ethical concerns have been raised. Like many other “dual use technologies,” synthetic biology offers the potential for great good, but also for harm. There are concerns that the increasing accessibility of this technology may spawn a new era of “biohackers” leading to the accidental or deliberate creation of pathogenic biological components.

Several options have been put forward in response, such as establishing a regulatory body to oversee and establish guidelines for the developing community. Safety measures taken by the research community include incorporating genetic signals that prevent uncontrolled spreading outside the lab environment. It is worth noting that in many ways, these mechanisms are already in place as part of the guidelines developed for recombinant DNA techniques that are currently in widespread use worldwide. From this perspective, the advances in synthetic biology may be viewed as a natural extension of this research, rather than a great leap into unchartered scientific territory.

– Dr. Neil Lamb
director of educational outreach
HudsonAlpha Institute for Biotechnology