SYNTHETIC BIOLOGY

Biotechnologists have long been able to take an organism and modify it to make it more useful to humans. By inserting genes here or cutting genes there, it has been possible to turn microbes into tiny protein factories, design better crop varieties and study human disease in animal models. Now, scientists working in the field of synthetic biology are exploring ways in which technology can not only alter life, but create it.

The fundamental concept of synthetic biology is not unlike how an engineer might assemble a chemical plant — but instead of pumps, reactors and filters, synthetic biologists work with a toolbox full of genes, proteins and other biomolecules. Their goal is to produce new living systems that, when deployed in the lab under controlled conditions, have desirable properties — for example, the ability to make complex products and materials or detect environmental changes. Although the field of synthetic biology is still young, its proponents expect it to lead us to an exciting new era in biotechnology.

CELL UPGRADE

The most fruitful line of research has involved a ‘top-down’ approach — starting with an unmodified or simplified cell and adding foreign elements or modules (Fig. 1). These might consist of genes encoding proteins that synthesize a molecule of interest in a sort of microscopic assembly line, or that cause a detectable change in response to an incoming signal. Although the field of synthetic biology is still young, its proponents expect it to lead us to an exciting new era in biotechnology.

The development of ‘protocells’ that mimic the fundamental structural and functional principles of real cells is therefore a major goal of bottom-up research. By reproducing simple biological phenomena in vitro, researchers at the Max Planck Institute of Biochemistry have made important progress in producing biomimetic bottom-up systems. Vogel, S. K. et al. (eLife 2013;2:e00116) reconstituted a minimized actin cortex, the mesh that supports cell membranes. Meanwhile, Zieske, K. & Schwille, P. (Angew. Chem. Int. Ed. 52 459–462; 2013) have shown that proteins required for cell division in bacteria can self-organize to form dynamic patterns and oscillations in artificial membrane compartments.

The goal of synthetic biology is to produce novel living systems with desirable properties.
Like engineering, synthetic biology involves building new biological systems from units and modules.

Scientists have already produced organisms that make drugs or biofuels, and have pieced together a synthetic organism using only genetic data.

In collaboration with other fields, synthetic biology could transform biotechnology and generate useful insights into the foundations of life.

Figure 1 | Top-down and bottom-up approaches to synthetic biology.

The near future of the field will lean heavily on the top-down approach — minimal systems derived from an existing organism. Bottom-up approaches (those that start from first principles) might allow us to refine these minimal systems with synthetic or biological components, but it remains unclear whether exclusively bottom-up systems will ever cross into the realm of living matter.

BRINGING THE CONCEPT TO LIFE

One of the great challenges for both top-down and bottom-up synthetic biology is identifying the minimal set of components needed for core processes, such as cell division and the generation of energy from nutrients, to take place. Uncovering these primal elements of cellular function, and then learning how to fit them together into new scaffolds, will involve both top-down and bottom-up approaches, and will take years of hard work by scientists in a broad range of disciplines. However, the ultimate rewards for this effort may be a richer understanding of what it means to be alive.


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