ALINA CHAN/HARVARD MEDICAL SCHOOL

A 'bionic leaf' that mimics photosynthesis.

SYNTHETIC BIOLOGY

Enter the living machine

Herbert Sauro delves into a history of attempts to engineer life.

In 2000, two landmark papers started a revolution in our ability to design entirely new functions inside cells. The authors took two electronic circuits — an oscillator and a switch — and built the equivalent from living matter (M. B. Elowitz and S. Leibler *Nature* **403,** 335–338 (2000); T. S. Gardner *et al. Nature* **403,** 339–342; 2000). Life became a machine. To many, including me, this was a profound moment: the beginning of the field of synthetic biology. Now an international enterprise with the potential to transform our lives, synthetic biology crosses age and organizational boundaries, and involves large corporations, small start-ups, academics and tinkerers.

In *Synthetic*, talented science historian Sophia Roosth describes her observations of the field's early evolution — the fruit of embedding herself in the working lives of synthetic biologists at the Massachusetts Institute of Technology in Cambridge. She chronicles the adventures of players such as bioengineer Drew Endy and computer engineer Tom Knight, who championed the field. She covers highlights including whether we can patent new life and how automation is changing the way we do biology. She looks at biologist George Church's dream of resurrecting the woolly mammoth. And she examines the start of the do-it-yourself synthbio scene, in which amateurs set up labs in garages and bedrooms.

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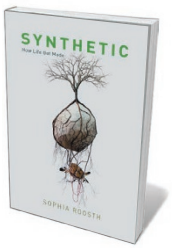

Synthetic: How Life Got Made
SOPHIA ROOSTH
University of Chicago Press: 2017.

Roosth conducted some interviews at the University of California, Berkeley, as well as at the Joint BioEnergy Institute and Amyris Biotechnologies in nearby Emeryville, where metabolic engineering is the primary interest. One surprising insight that she gathered was the difference in scientific cultures. The east-coast scene, as one interviewee notes, is "super all positive, group love". The west is more corporate — a reversal of expectations.

Roosth's approach sparks deep questions about the nature of life. At Berkeley, she and bioengineer Adam Arkin discussed what makes a pig gene a pig gene. He said that this isn't a meaningful question: out of context, the gene has no "pigness". Thus, Roosth asks, how do we define species in the synthetic world, and what does it mean to move genes from one organism to another? More profoundly, what does 'synthetic' even mean?

Roosth delves into different interpretations. For instance, when organic chemistry was emerging in the eighteenth century, 'synthetic' referred to making organic compounds by human agency. In 2010, the biotechnologist Craig Venter claimed to have created synthetic life (D. G. Gibson *et al. Science* **329,** 52–56; 2010). His lab inserted the genome of the bacterium *Mycoplasma mycoides* (synthesized and slightly modified) into a 'dead' cell of a closely related organism, revivifying its protoplasm (see N. Comfort *Nature* **502,** 436–437; 2013). Was the synthetic element in this process the use of carbon, hydrogen and oxygen from non-living sources? Was it that the inserted DNA had been built from a slightly altered sequence on a computer's hard drive? Or was it the act of creating a new biological cell by human intervention?

I do have quibbles. Roosth's focus is exclusively on US labs. The dearth of coverage of Europe — except for a passing comment on Dolly the sheep, cloned at the Roslin Institute outside Edinburgh, UK — makes *Synthetic* a little one-sided. There are other omissions. For example, Roosth hardly discusses the pioneering work by James Collins at Boston University in Massachusetts and his colleagues: they created one of the first synthetic circuits in a cell.

Yet the chapter on DIY synthbio is a welcome reminder of the excitement I remember from the late 1970s, when amateur groups helped to drive the desktop-computer revolution. Hobbyist groups are still emerging in biology, such as the non-profit SoundBio Lab, founded by synthetic biologist Michal Galdzicki, data scientist Zach Mueller and science educator Regina Wu in Seattle, Washington — my home town. I suspect that the main role of these organizations will not be in inventing new life, but in teaching the general public; less grand, but equally important.

Synthetic biology holds great promise in delivering new sources of energy and materials, therapeutics and, most exciting of all, regenerative medicine. What might stymie future development is funding. Currently, basic science funding in the United States is extremely uncertain; it could be dramatically curtailed in the next five years. Meanwhile, Europe and China are boosting their basic research in synthetic biology — and could eventually become dominant players. ■

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