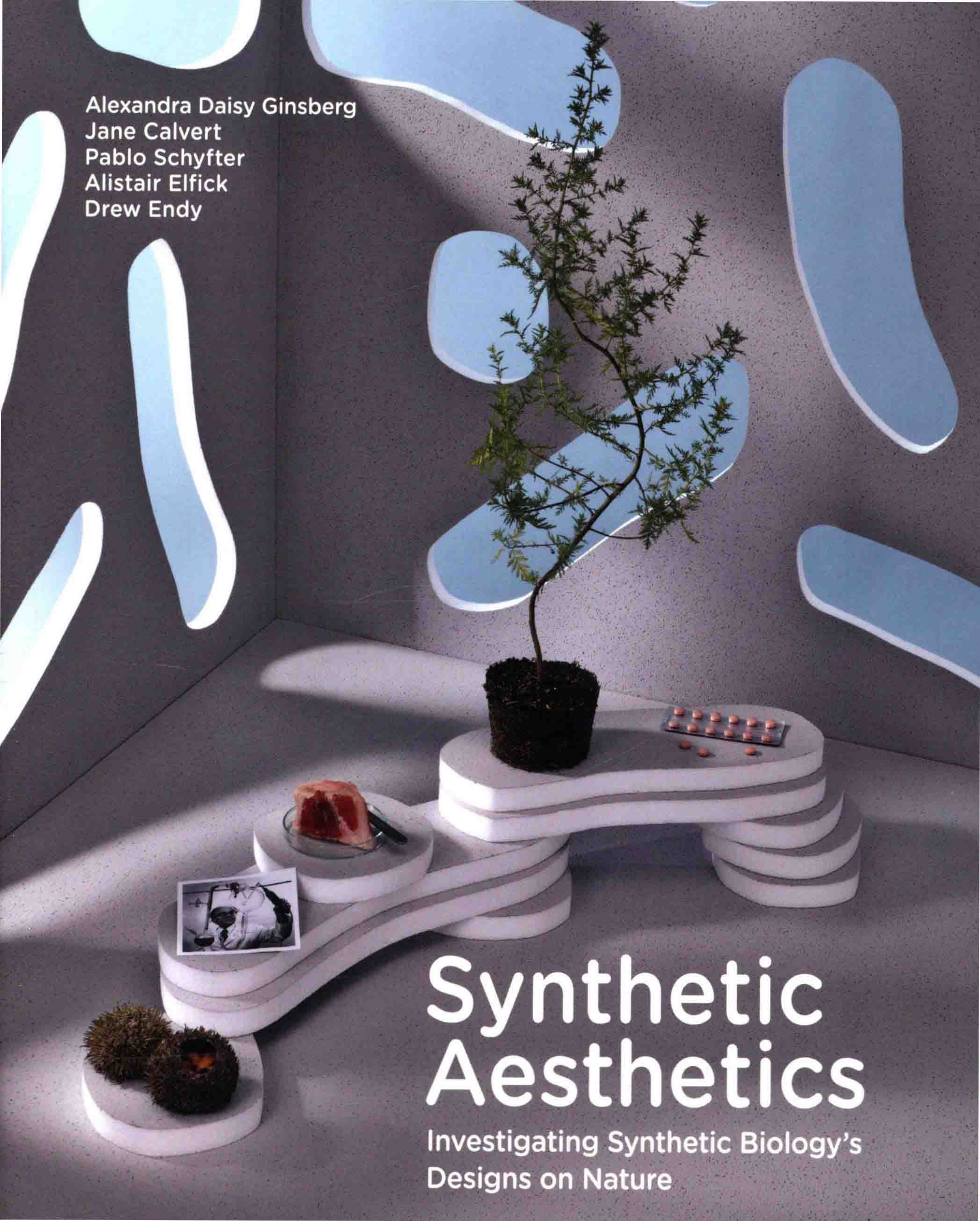

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Synthetic Aesthetics

Investigating Synthetic Biology's Designs on Nature

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Alexandra Daisy Ginsberg, Jane Calvert, Pablo Schyfter, Alistair Elfick, and Drew Endy

biology/design

Synthetic biology manipulates the stuff of life. For synthetic biologists, living matter is programmable material. In search of carbon-neutral fuels, sustainable manufacturing techniques, and innovative drugs, these researchers aim to redesign existing organisms and even construct completely novel biological entities. Some synthetic biologists see themselves as designers, inventing new products and applications. But if biology is viewed as a malleable, engineerable, designable medium, what will be the role of design and how will its values apply?

The book follows six boundary-crossing collaborations between artists and designers and synthetic biologists from around the world. These collaborations have resulted in, among other things, biological computers that calculate form; algae that feeds on circuit boards; and a sampling of human cheeses. Synthetic biology is driven by its potential; some of these projects are fictions, beyond the current capabilities of the technology. Yet even as fictions, they help illuminate, question, and even shape the future of the field.

Alexandra Daisy Ginsberg is a London-based artist, designer, and writer. Jane Calvert and Pablo Schyfter are social scientists based in Science, Technology and Innovation Studies at the University of Edinburgh. Alistair Elfick is Professor of Synthetic Biological Engineering and Deputy Director of the UK Centre for Mammalian Synthetic Biology at the University of Edinburgh. Drew Endy is a bioengineer at Stanford University and President of the BioBricks Foundation.

"Just as postwar designers Ray and Charles Eames showed us how molded plywood techniques for building airplane wings could result in unexpected, and now timeless, pieces of furniture, artists and designers like Daisy Ginsberg are showing us how bacteria and other biological building blocks may give us entree to an entirely new species of experiences."
—John Maeda, Global Head of Computational Design and Inclusion, Automattic

"A timely overview that seeks to raise questions, rather than provide answers."
—Jonathan Openshaw, *PostMatter*

"Offers a range of ways designers and artists from very different points on the creative spectrum can critically engage with this exciting field."
—Anthony Dunne, Head of the Design Interactions Programme, Royal College of Art

The MIT Press
Massachusetts Institute of Technology
Cambridge, Massachusetts 02142
http://mitpress.mit.edu

978-0-262-53401-7

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with additional contributors

The MIT Press Cambridge, Massachusetts London, England

First MIT Press paperback edition, 2017

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This book was set in Plantin and Gotham Rounded by the MIT Press. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data
Synthetic aesthetics : investigating synthetic biology's designs on nature / by Alexandra Daisy Ginsberg ... [et al.].
p. ; cm.
Includes bibliographical references and index.
ISBN 978-0-262-01999-6 (hardcover : alk. paper)—978-0-262-53401-7 (pb.)
I. Ginsberg, Alexandra Daisy.
[DNLM: 1. Synthetic Biology—trends. 2. Art. 3. Biotechnology—trends.
4. Esthetics. QT 36]
QP517.B56
610.284—dc23
2013013618

10 9 8 7 6 5 4 3 2

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Synthetic Aesthetics

Acknowledgments

We would like to express our gratitude to all of those whose help was crucial to the project and this book. Neither would have been possible without the generous support of the Engineering and Physical Sciences Research Council (EPSRC) and the National Science Foundation (NSF) and their ongoing enthusiasm for our work. We would also like to acknowledge support from a Royal Academy of Engineering Ingenious Award, a Wellcome Trust Arts Award, the Economic and Social Research Council (ESRC) Innogen Centre, and the School of Engineering at the University of Edinburgh. Dozens of other institutions around the world have been vital to our work. We are grateful to the various workspaces and their members—laboratories and studios alike—that hosted the residents and supported this endeavor. We have also benefited from feedback from those who have been part of many different conversations, symposiums, lectures, and workshops associated with the project.

In writing this book, we have received thoughtful and useful comments from several colleagues. We are especially indebted to Christina Agapakis, Patrick Boyle, David Crowley, Emma Frow, and Sheref Mansy for their help in this capacity. We also wish to thank Kellenberger-White for creative direction, China Brooks-Basto for production assistance, Drusilla Calvert for indexing, as well as all of those who have contributed images to this book. We would particularly like to acknowledge all the administrative and support staff at the University of Edinburgh, Stanford University, and elsewhere who made such a big, international project happen.

Finally, we would like to thank the Synthetic Aesthetics residents and all the contributors to this book for their participation, their ideas, and their commitment to the project well beyond its official time frame. These individuals' energy and creativity made both the project and this book possible.

Introduction: How Would You Design Nature?

Circuitry, toggle switches, gates, sensors, oscillators. This is the language of component parts and manufacturing, of robots and computers and digital logic. It is not the language of life and death, of protein tangles, evolution, reproduction and decay, the everyday struggles of biological matter. Yet this is now biology, albeit a new engineering approach to bioscience—the emerging field of synthetic biology.

The nineteenth century was shaped by the mechanization of the Industrial Revolution; in the twentieth century, the silicon circuitry of an Information Revolution restructured modern life. Now, some predict biotechnology will be the foremost driver of change for the twenty-first century, and synthetic biologists believe that their work will be integral to the success of this envisioned "Biotechnology Revolution" through the intentional design (or redesign) of biology.

Synthetic biology is a young field with growing global momentum, enticing engineers, biologists, chemists, physicists, and computer scientists to the laboratory bench to manipulate the stuff of life. These self-styled pioneers of biological engineering aspire to redesign existing organisms using engineering principles like standardization; some even seek to construct completely novel biological entities. The field's engineering vision leads to parallels being drawn with the early days of computer technology, as researchers reimagine bits of DNA code as programmable parts, analogous to the components of computer software and hardware (figure I.1). At the human scale, some synthetic biologists compare their culture to the garage innovators of the 1970s and 1980s who built the first personal computers and laid the foundations of a new industry. For synthetic biologists, biology could be just another material to engineer, its living machines driving twenty-first century progress.

What motivates this desire to make biology predictable and functional, to design biology rather than to understand it? Many synthetic biologists aspire to improve so-called genetic engineering. For these researchers, genetic engineering is less engineering than craft; it is an approach that can deliver unique products but not systematic tools and techniques. A genetic engineer may transfer the gene for an antifreeze protein from a fish into a tomato to make cold-resistant fruit, but the solution is only a one-off. Synthetic biologists instead hope to lay the foundations for a faster, more efficient, repeatable, and ultimately cheaper way to engineer living materials. Just as the standardization of the screw thread united individual manufacturers and users of nuts and bolts, and thereby helped drive the Industrial Revolution, this kind of bioengineering, it is hoped, will enable a Biotechnology Revolution. In short, synthetic biologists want to be reliably able to insert an antifreeze gene into any number of other organisms, including bacteria, with predictable results every time. Biology doesn't necessarily work in this way, but by applying engineering design principles—such as standardization—synthetic biologists seek to transform it (figure I.2). Future biological designers may even work far from the lab bench, dragging and dropping component parts using design software similar to that used by architects or programmers, expecting the same level of control over the materials they engineer.

This technical ambition is driven by dreams of plentiful, sustainable fuel, new manufacturing techniques, novel drugs and materials, and medical technologies (figure I.3). Through synthetic biology, living things could become both the operating system and the machine, in theory creating a technology

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Figure I.1
Revolution or evolution? A film of genetically modified, light-sensitive bacteria displays the classic computer program message. These *"E. coloroid"* bacteria were engineered by undergraduates from the 2004 University of Texas, Austin and University of California at San Francisco iGEM team.

so versatile that it could be used to produce the food for a projected global population explosion and remediate the environmental damage wreaked by two centuries of industrial modernization.

This vision of a biology transformed into a medium and material for design is accompanied by grand rhetoric of a world-changing, world-saving green technology. Although such ambitions are admirable in their scope, they raise many questions. What is the potential for unintentional, or even intentional, damage caused by biotechnologies? How are we to manage the ownership of life's materials? These issues have been and continue to be much scrutinized by bioethicists, social scientists, and policy makers. But

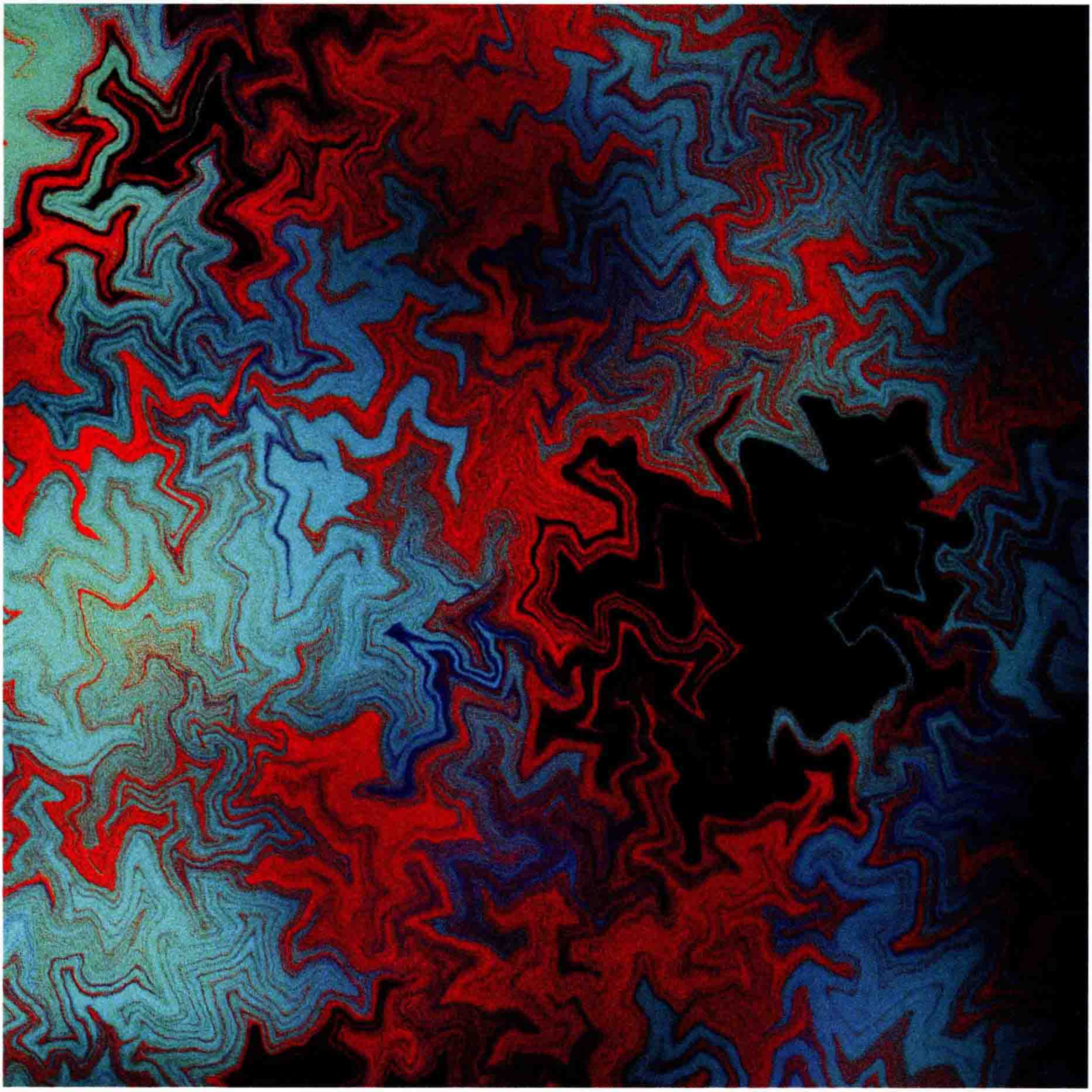
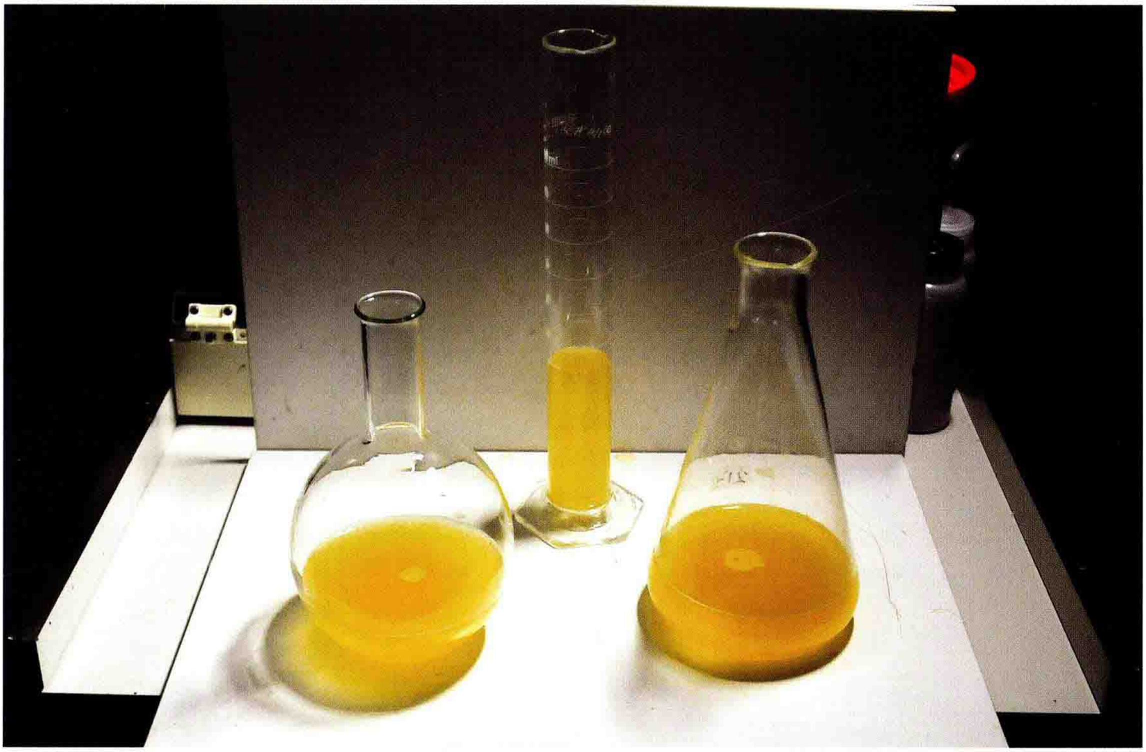
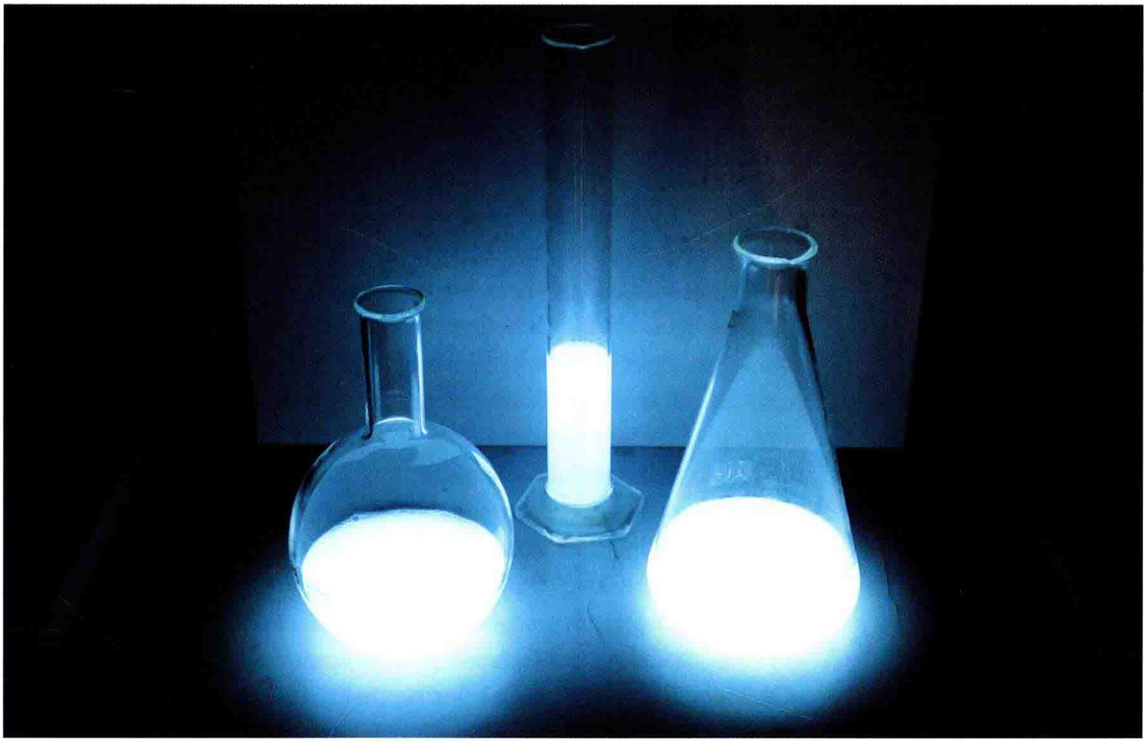


Figure I.2
Bacteria have become the workhorses of synthetic biology. Here, biologist Fernan Federici "labels" *Bacillus subtilis* to fluoresce, tracking their self-organized pattern formation, as seen in an optical microscope at ×1000 magnification.

Figure I.3
Synthetic biology is described as a transformational technology. In 2010, synthetic biology students at the University of Cambridge engineered these *Escherichia coli* bacteria—dubbed "*E. glowli*"—to bioluminesce extra-brightly.





synthetic biology also presents complex new issues that are not often discussed, such as the path of the technology's development, the direction we want it to take, and how the aims of synthetic biologists align (or fail to do so) with those of the technology's potential users: us all.

Despite being a young field, countless reports have been written on synthetic biology and the social, ethical, and legal issues it raises.[1] Up until now, much of this discussion, both of sustainable futures and risk, has been speculation. But now we are at a point in time in which synthetic biology is becoming increasingly mainstream and is receiving growing financial support across the globe. At the time of writing, the largest public funders of the field are the Chinese, U.S., and U.K. governments. As synthetic biology develops, its practitioners are beginning to orient their work toward industrialization, slotting into existing and accepted ways of manufacturing. There is a danger that synthetic biology will become myopic and monolithic, following the well-trodden path of industrialization, including first generation industrial biotechnology. Synthetic biology may simply become a way of pumping out more of what we already have—such as fuels or plastics—using biological rather than non-biological processes. This new technology could be used to give a green gloss to harmful practices like inefficient production, excessive consumption, and toxic waste—the problematic aspects of "successful" industrialization (figure I.4).

Alternative visions of synthetic biological consumer products range from the mundane or frivolous (like probiotics and diet pills) to the imaginative and challenging (such as plants engineered for pleasure or living building materials). Could synthetic biology perhaps change our lives in these unexpected ways? The promise of the technology may well be no more than hype, yet these discussions demand society's attention and participation. They should not be limited to a select few with a controlling stake in the technology.

This book about synthetic biology is unusual in that it presents an ongoing dialogue between synthetic biologists, artists, designers, and social scientists, all with very different views on this emerging technology. We draw on a diversity of perspectives and projects to explore and challenge the understanding of design in synthetic biology. Our aim is to provoke discussion about what place—if any—design should have in our relationship to living things. What does design in synthetic biology really mean and what might it involve? What responsibilities does designing biology carry, and what consequences could it have? This focus on design allows us to question, challenge, and reconsider the assumptions made about the future of this developing technology, one normally rendered through contradicting visions of utopian green salvation or dystopian bio-apocalypse. We are

seeking ways to understand better the scientific, technological, ethical, philosophical, political, and social dimensions of synthetic biology using art and design to identify new areas for enquiry.

Instead of finding solutions to predefined problems, we propose that we should be challenging the questions that are being asked. We see many reasons for advancing alternative perspectives on synthetic biology, as it is in the process of being developed. First, there are technical arguments about biology itself. Rather than treat living nature as just another material for engineering, synthetic biology may benefit from engaging with its unique properties, which, though complex and unpredictable, might suggest new approaches and perspectives to using life as a raw material. Second, synthetic biology is often promoted as a sustainable solution to our manufacturing and energy woes, but there is a paradox in this reasoning. Industrialization and design are oriented toward growth, not equilibrium

Figure I.4
Will synthetic biology simply feed into existing systems of use, consumption, and waste or could we design more from it? Photographer Chris Jordan documents today's detritus in "Intolerable Beauty: Portraits of American Mass Consumption, Crushed Cars #2, Tacoma 2004."

Figure I.5
Massive algae bloom in 2011 at Qingdao Beach, China, triggered by water pollution.

and sustainability. Biology grows within the balance of ecosystems, but can commercial synthetic biology be a sustainable, renewable technology on a planet with finite resources (figure I.5)? There may be alternative strategies to explicit industrialization that could better address the problems that synthetic biology purports to solve; approaches that are novel, imaginative, and more suitable for designable biology. Engineering biology appropriately could help us address profound problems in the logic of production and consumption that underpin design and engineering today. But it is clearly not the only way to address these challenges. It is important to ask when and whether we should be turning to synthetic biology, rather than to other technical, social, or political solutions. Asking disruptive questions like this may not be comfortable, but it can be productive, making things visible that otherwise would not be so. Our aim is not celebration, but exploration and interrogation of the expectations and limitations of synthetic biology.

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