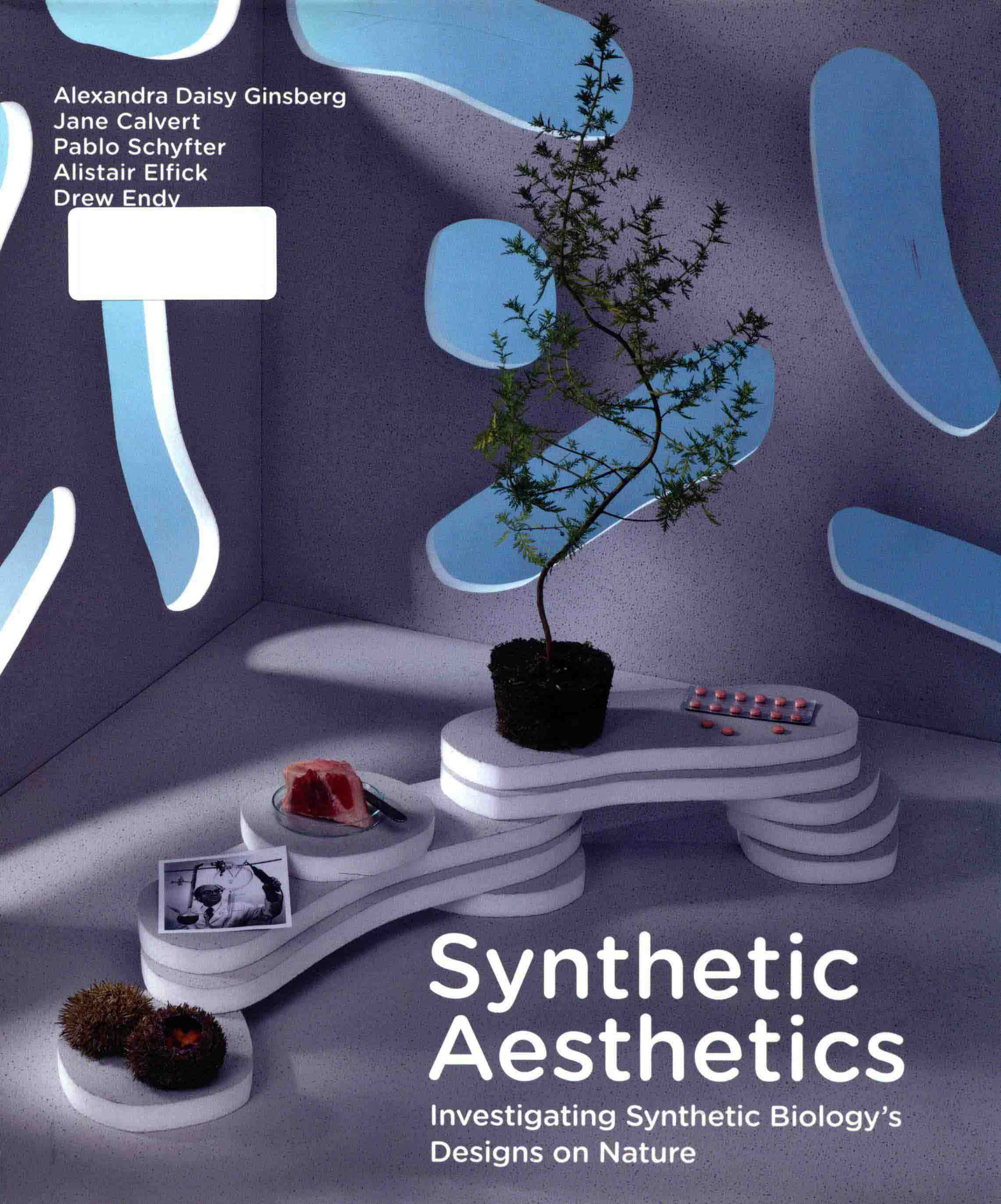

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Synthetic Aesthetics

Investigating Synthetic Biology's Designs on Nature

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Synthetic Aesthetics

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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

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.

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.

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

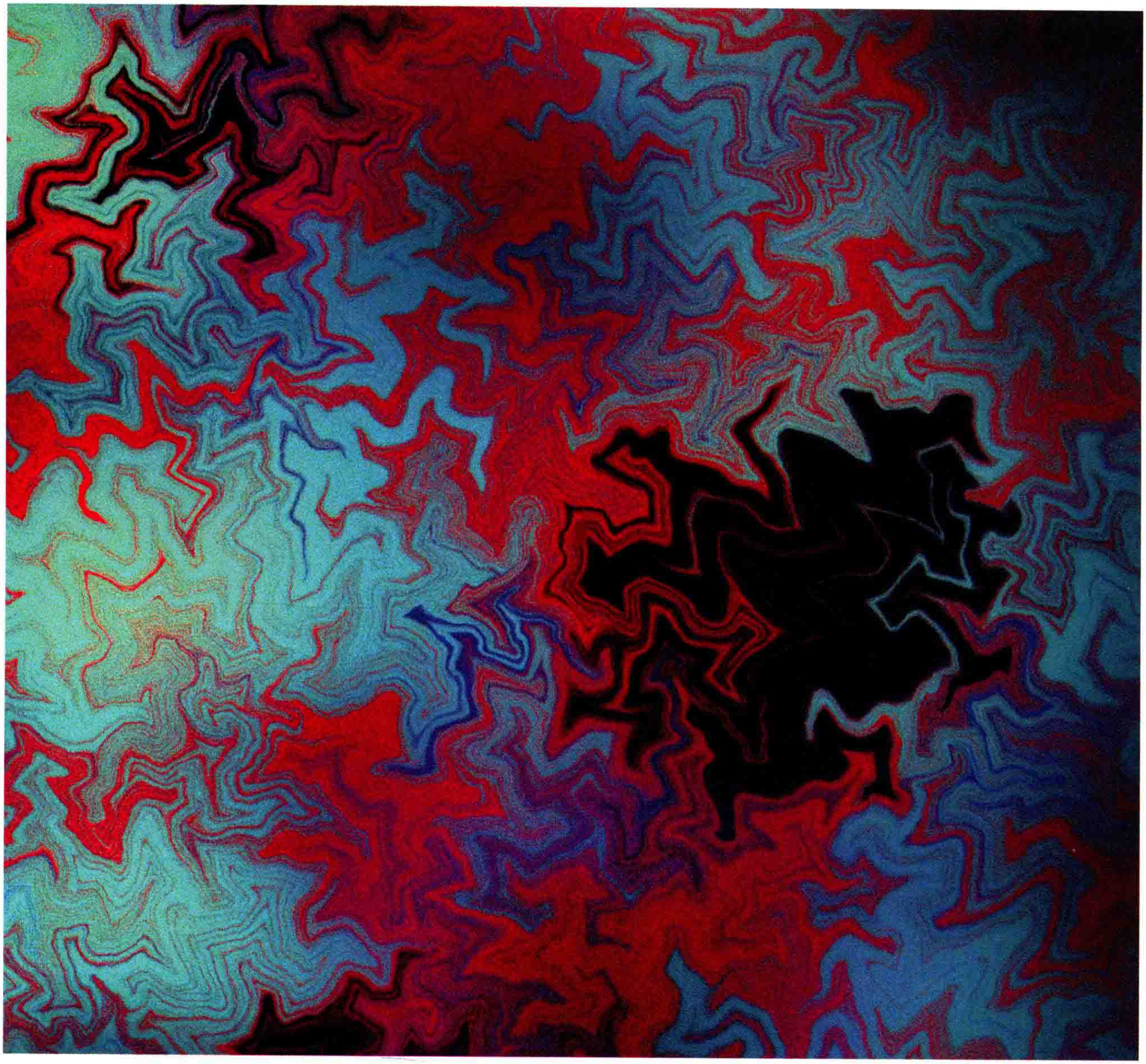
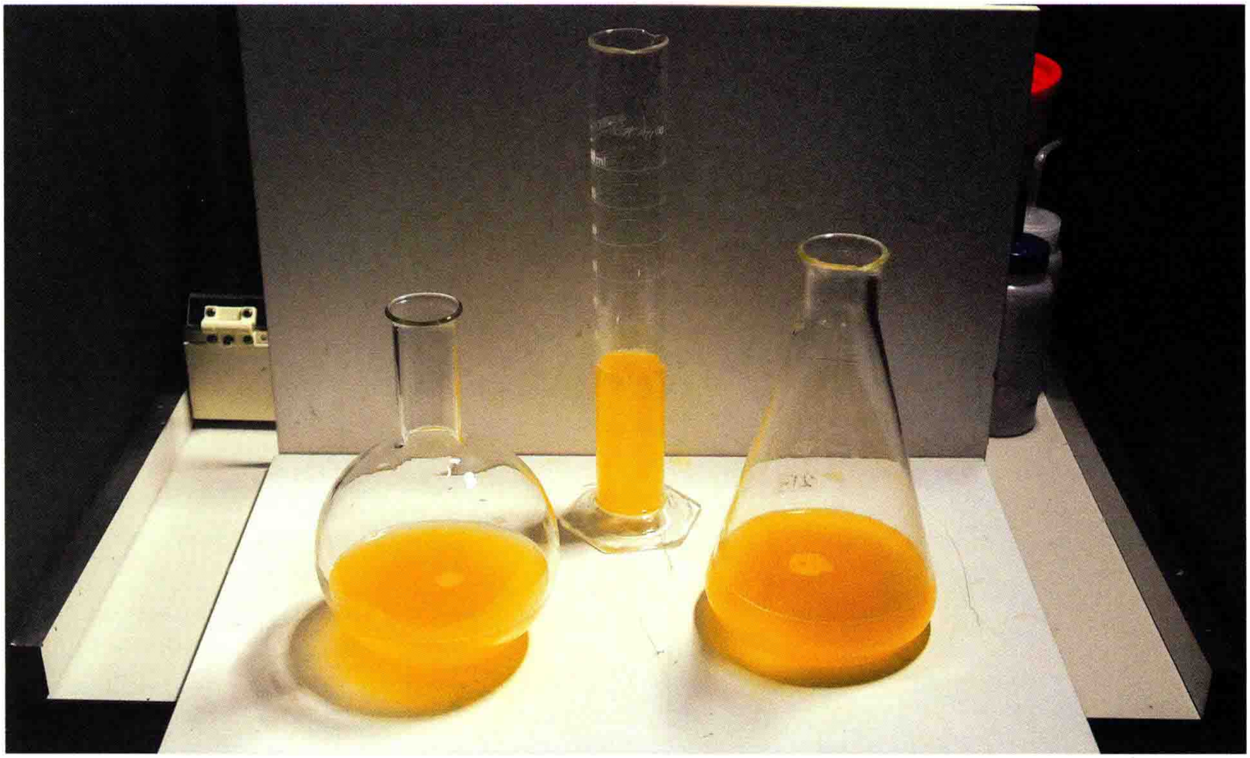
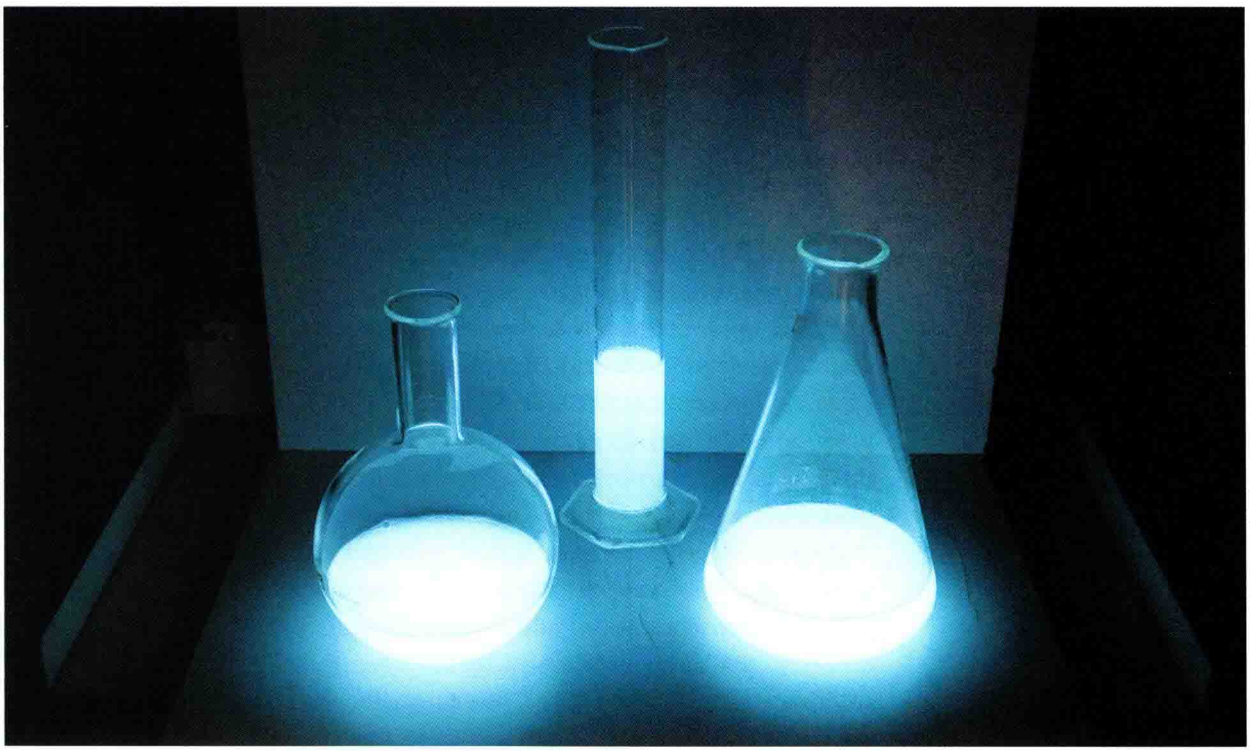


Figure 1.2
Bacteria have become the workhorses of synthetic biology. Here, biologist Fernan Federici "labels" *Bacillus subtilis* to fluoresce, tracking their self-organized pattern formation, as seen in an optical microscope at ×1000 magnification.

Figure 1.3
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."

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.

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

The Synthetic Aesthetics project team comprises two synthetic biologists with engineering backgrounds, two social scientists, and a designer/artist. As part of the project, we have all been forced to engage with unfamiliar perspectives and to challenge our disciplinary assumptions, finding new ways of working that have taken us beyond what we could have done in our separate disciplines. Synthetic Aesthetics is not specifically an engineering or science, social science, or art or design project but it draws on all these areas. Although our focus is synthetic biology, we are investigating the values and assumptions that could affect us all, beyond those actively working in the field.

We want to generate discussion about synthetic biology, its aims, and its potential implications, using art, design, and social science to transcend the narrow and one-dimensional way in which it is starting to be framed in order to stimulate more improbable and creative thinking. This requires not merely considering our needs today, but enabling novel paths that will allow biology, technology, and society to interact in new ways in the future. We hope to increase the range of possibilities and future trajectories for technological development and to promote better outcomes—with the recognition that what is meant by "better" is something that must be actively and continually debated.

Origins

The unusual origins of the Synthetic Aesthetics project help explain the unconventional nature of the research. The project was conceived, developed, and funded over just five days as part of a workshop held outside Washington, D.C., in March, 2009. The "IDEAS Factory Sandpit on New Directions in Synthetic Biology" was organized and funded by the Engineering and Physical Science Research Council (EPSRC) of the United Kingdom and the National Science Foundation (NSF) of the United States. Leading academics in synthetic biology from across the United States and the United Kingdom came together to develop grant proposals from scratch. "Sandpits" are not a normal research funding mechanism; they are an unconventional method used to foster innovative interdisciplinary research proposals in a very short time period, in contrast with the typical lengthy grant-writing process accompanied by the conservatism of peer review common in science today. Sandpits are intense: Participants subject each other's proposals to "real-time" peer review, successful projects are funded by the close of the workshop, and new collaborations are cemented.

An ideal sandpit project is meant to be multidisciplinary, transformative, novel, and innovative, and participants are encouraged to put forward risky and adventurous proposals encroaching on new territory. "Synthetic aesthetics" started as an anonymous phrase written on a Post-It note and stuck to a wall. It captured the interest of the three of us who attended the sandpit (Jane Calvert, Alistair Elfick, and Drew Endy). We speculated about what would happen if we initiated collaborations between synthetic biologists and creative communities that allowed both groups to imagine their work in new ways. We took seriously the organizers' encouragement to "think outside the box" by performing a dance based on the myth of the Golem to present some of our early ideas. We had discussions about the sublime. We were challenged by our colleagues to define beauty and defend frivolity. What resulted from this strange and intense experience was a project that was completely unexpected. When we wrote our original proposal at the sandpit, one of our hypotheses was "we will be surprised." This has proved to be a good working hypothesis.

During the sandpit and since, some people have assumed that our aim is outreach: a public relations activity on behalf of synthetic biology to beautify, package, sanitize, and better communicate the science. We reject and actively resist such a framing. Our project has been an exploratory investigation of the intersection between art, design, and synthetic biology, encouraging dialogue and dissent. Creating a space for critique continues to be a guiding principle of Synthetic Aesthetics.

The Synthetic Aesthetics Residencies

The core of the project has been the curation of paired residencies between six artists and designers and six synthetic biologists working in Europe, Asia, Australia, South America, and the United States. Their shared expertise extends across the spectrum of synthetic biology, from plant science to protocell research, and encompasses a diversity of approaches to art and design, including architecture, music, smell design, bio art, and product design.

We received hundreds of applications from designers, architects, writers, dancers, painters, artists, chemists, biologists, computer scientists, and engineers who wanted to participate in the project. We intentionally selected artists and designers whose work was not primarily concerned with visualization—translating science into images or objects. Instead, we chose those who were interested in directly engaging with the subject matter of synthetic biology. The Synthetic Aesthetics team matched up the pairs (except for Oron Catts and Hideo Iwasaki, who applied together). We sought out themes that linked the residents' work—some almost imperceptible at first—and that we hoped would generate unexpected insights (figures I.6 and I.7).

Tasked with investigating design and synthetic biology, the Synthetic Aesthetics residents had explicit freedom to take their work in any direction they chose. Art/science projects often involve artists visiting—even working—in labs, but it is unusual to extract scientists from their work environment and

Figure I.6
Workspace of a Synthetic Aesthetics resident: Christina Agapakis's lab bench in the Silver Lab at Harvard University Medical School.

Figure I.7
Workspace of a Synthetic Aesthetics resident: Sissel Tolaas's smell-molecule studio in Berlin.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put them in a studio as part of these collaborations. For our program, each residency began with an intensive two-week period in one partner's laboratory and then continued by moving to the artist/designer's studio for two weeks. Both stages were documented by the project team. These two-way exchanges were intended to encourage reciprocal collaborations that could contribute to both partners' practice. At the time of writing, two years after the residencies began, all our residents continue to collaborate. Their research together is described in their contributions to Part Three of this book.

We were encouraged that a large number of scientists and engineers wanted to participate in a project beyond the remit of their "normal" responsibilities. It may be that aspects of synthetic biology make it well suited to this type of unconventional initiative. It is already an extremely interdisciplinary field, so it may not be as much of a stretch to involve artists, designers, and social scientists as it might be in a more established, traditional discipline. In addition, some synthetic biologists explicitly aim to "make biology easier to engineer" and to make the science more accessible to the outsider. But perhaps the most important reason why synthetic biologists are open to these kinds of collaborations is because they are part of a new field that has not yet stabilized. The relationships between science, engineering, and society are still being created and negotiated, providing opportunities for interdisciplinary investigation, experimentation, and debate. Through the project, we wanted to increase the range of people who have a voice in the future of synthetic biology and who can contribute to decisions about the directions it may take. Our long-term aim is to enable new groups of practitioners, thinkers, and critics to engage with developments in synthetic biology and to broaden the conversation about how we should best make use of our abilities to manipulate the natural world. But as the field becomes more established, will initiatives like Synthetic Aesthetics be harder to instigate?

Nature, Biology, and Design

Part One of this book introduces our two key areas of interest: synthetic biology and design. In chapter 1, Alistair Elfick and Drew Endy, both engineers by training, introduce synthetic biology and describe their vision of using biology as a material for design by harnessing its unique properties. In direct contrast to the engineers, in chapter 2 artists Oron Catts and Ionat Zurr express their concern that we are moving into a future dominated by a single engineering paradigm. They argue that the "engineering mindset," which has developed over the past century, threatens to monopolize life. One way of drawing attention to alternative frames of thought, they maintain, is to open up the tools and spaces of biotechnology to other disciplines, including art. In chapter 3, the designer and artist Alexandra Daisy Ginsberg investigates