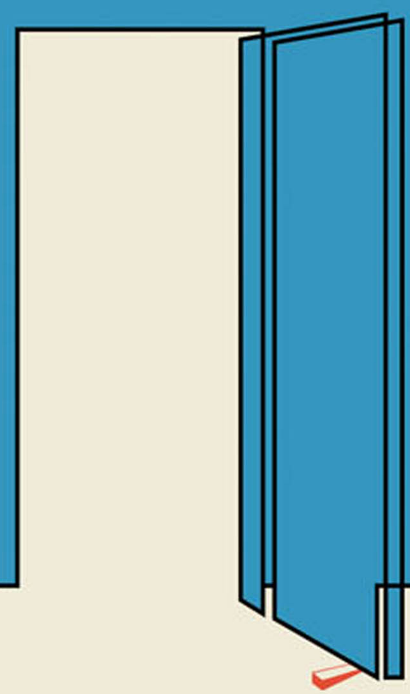
A Place for Science and Technology Studies

Observation, Intervention, and Collaboration



Jane Calvert

A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

OBSERVATION, INTERVENTION, AND COLLABORATION

JANE CALVERT

The MIT Press
Cambridge, Massachusetts
London, England

The MIT Press would like to thank the anonymous peer reviewers who provided comments on drafts of this book. The generous work of academic experts is essential for establishing the authority and quality of our publications. We acknowledge with gratitude the contributions of these otherwise uncredited readers.

This book was set in Stone Serif and Stone Sans by Westchester Publishing Services.

Library of Congress Cataloging-in-Publication Data is available.

ISBN: 978-0-262-54694-2

Dedicated to
Drusilla Calvert (1944–2021)
Andrew Webster (1951–2021)

CONTENTS

PREFACE

This is a book about rooms—so let this preface be an open door to welcome you into the entrance hall. Although the rooms that the hall leads into may be more enticing, there are a few anomalous items stored here that might benefit from a brief explanation. The first is a pile of what seem at first glance to be LEGO bricks, which on further investigation are rather more organic than would be expected. Then there is a coat hanging on a hook that clearly has not been worn for several months. In the pocket are some out-of-date boarding passes. On the wall is a framed photograph of a group of people who have just completed a long walk together.

The LEGO-like bricks represent a field called synthetic biology, which arose in the 2000s with the aim of making biology easier to engineer by applying engineering principles to living systems. In its early days, efforts focused on attempting to build standardized interchangeable parts from biological materials, and the LEGO brick was the aspirational analogy of choice. Before going any further, I should say that this is not a book about synthetic biology—but it does make a significant appearance in nearly every chapter. This is because my social scientific investigation of synthetic biology is what pushed and inspired me to write about a place for science and technology studies (STS). Synthetic biology took me to many different rooms and helped me see that observation, intervention, and collaboration were legitimate methodological orientations in different locations. Synthetic biology made me want to ask questions about my work that are often left tacit or implicit: questions about what it is to do STS, where STS belongs (if anywhere), and what it brings that is distinctive.

The coat has not been worn because the owner has not left their house for the past 18 months. The boarding passes are poignant reminders of the world before 2020, when the majority of this book was written. This was when, even in the face of escalating climate concerns, international travel remained unexceptional, and close encounters with multiple people in the same room were not a source of anxiety. At its height, the global pandemic made the kind of easy movement between different locations discussed in these pages almost inconceivable, even within the same town or city. The only room that it seemed feasible to write about was the Zoom room or a similar commercially owned online space. But this is not a book about online spaces. Although they are undoubtedly important, they are not where my most significant interactions with my field of study (synthetic biology) have taken place. Now, in summer 2022, things are shifting again, and we may soon forget those months of screen-facilitated isolation, although many of us have become particularly sensitized to the uncertainty of the future.

The framed photograph is pre-pandemic. Taken in front of the impressive red rocks and canyons of Sedona in Arizona, it is a picture of a research team funded by the European Research Council (ERC) for a project called Engineering Life, a collaboration between the University of Edinburgh and Arizona State University. This was a social scientific project focused on synthetic biology, which examined the movement of ideas, practices, policies, and promises from engineering to the life sciences. The photo is reminiscent of those that scientists show of their lab members at the end of their presentations, which admittedly feels a little odd for a group of social scientists. But it is significant because it points to the unique opportunity the ERC provided for a small research team to carry out a dedicated social scientific study of synthetic biology without being financially dependent on research grants from the natural sciences and engineering. Most importantly for me, for the duration of the grant, I had a group of wonderful colleagues to work with. I have also benefited tremendously from thinking with others both before and after the Engineering Life project. This is one reason I am ambivalent about the single-authored monograph as a publication output of choice—a topic I return to in the chapters that follow (with an awareness of the irony of doing so in this book).

The best place for acknowledgments is probably not in the hallway, but I do enjoy a metaphor, so I will leave them here because at least people will see them before they move on to other rooms.

ACKNOWLEDGMENTS

First, huge thanks to Emma Frow, who has informed and enriched my thinking about STS and synthetic biology ever since our first conversation in 2007. I have also benefited greatly from discussions with Daisy Ginsberg and Claire Marris. The Engineering Life project team members Dominic Berry, Annie Hammang, Thoko Kamwendo, Pablo Schyfter, D. Scott, Robert Smith, and Erika Szymanski all brought unique perspectives to the social studies of the life sciences. I am very grateful to Emma, Daisy, Pablo, Rob, and Erika for reading and commenting on chapters of the book. The writing of it coincided with D. Scott's move into editing, and their attentiveness and constructive sympathy for what I was trying to say has been invaluable in helping me improve the whole manuscript. Many thanks also to the three anonymous reviewers for their generous and thoughtful feedback.

Incisive points were made by those who participated in the Science, Technology, and Innovation Studies Work-in-Progress meetings at Edinburgh at which chapters of this book were discussed. I have also gained much from conversations with students, colleagues, and mentors including Ros Attenborough, Brian Balmer, Barry Barnes, Luis Campos, Yuning Chen, John Dupré, Anna Verena Eireiner, Joan Fujimura, Gill Haddow, Cate Heeney, Pierre-Benoit Joly, Michael Kattirtzi, Lorenzo Lane, Valentina Marcheselli, Fadhila Mazanderani, Chris Mellingwood, Maureen O'Malley, Simone Sambento, Tiago Santos Pereira, Sophie Stone, Steve Sturdy, Niki Vermeulen, Robin Williams, and Patricia Wu Wu. The ideas in this book owe much to joint writing with Paul Martin and collaborative work with Andrew Balmer, Susan Molyneux-Hodgson, Matthew Kearnes, Kate Bulpin, and Adrian Mackenzie. I am also grateful to Ben Collier and Donald Mackenzie for advice on the book proposal.

Many synthetic biologists I have interacted with have been very open to ideas in STS. Thank you particularly to Elise Cachat, Patrick Cai, Jamie Davies, Alistair Elfick, Tom Ellis, Drew Endy, Jim Haseloff, Louise Horsfall, Andrew Millar, and Susan Rosser. Thanks also to Patrick Middleton and Peter Mills for providing openings for STS in the policy room and the bioethics building, respectively. The Synthetic Aesthetics project had a large influence on my work and this book, and I have greatly benefited from interactions with Christina Agapakis, Oron Catts, Hideo Iwasaki, Sheref Mansy, and Ionat Zurr. Sascha Pohflepp, who sadly passed away in 2019, helped me to see the connections between art, design, and STS.

I have had many useful discussions of the ideas in this book at workshops, seminars, and conferences over the years, including at the University of Nottingham, the University of New South Wales, Korea Advanced Institute of Science and Technology, the University of Cambridge, the University of Tampere, King's College London, and most recently with members of the Body Societal ERC project group at their Scottish retreat. Thanks to everyone for their input.

I am particularly grateful to the master's students at the University of Vienna who took "A Place for STS" as an intensive course in June 2022 and whose imaginative engagement pushed the ideas further: Alexander Barth, Livia Beck, Hanna Braun, Gözde Çinar, Anna Dobrosovestnova, Elaine Goldberg, Max Karge, Ingrid Marin, Kaye Mathies, Georgie Moore, Anastasia Nesbitt, Patrik Pýcha, Celine Rabé, Fabian Saxinger, and Jana Wiese. Many thanks to Sarah Davies, Ulrike Felt, and Maximilian Fochler for giving me the fantastic opportunity to teach the course.

Collaborative work is highly dependent on funding (an issue I return to later in the book). I am grateful to have received support from the European Research Council (616510-ENLIFE), the Economic and Social Research Council (ES/I002111/1, ES/S013601/1, ES/V002600/1), the Biotechnology and Biological Sciences Research Council (BB/F018746/1, BB/M005690/1, BB/M018040/1), and the Engineering and Physical Sciences Research Council (EP/H01912X/1, EP/J02175X/1). The Brocher Foundation provided the ideal environment for thinking through ideas with Emma Frow and Pablo Schyfter in July 2018.

Katie Helke at the MIT Press, thank you very much for your ongoing support and for helping me with so many issues, large and small. I am also very grateful to Megha Azad for production editing, Karen Brogno and Nitesh Singh for copyediting, Christine Knight for proofreading, and Beverley Winkler for indexing.

Finally, I owe the most to Adrian Haddock, who has accompanied me since the earliest stages of the ideas and has talked through all of them with me, and who has commented on the whole manuscript with attentiveness, insight, and humor.

INTRODUCTION: WHY ROOMS?

> STSers can contribute to making things, to changing the world. In doing so, they inevitably will dirty their hands, for there is no free ride here.
>
> —Wiebe Bijker

I am packing for Singapore. It is difficult to imagine the heat and humidity of the tropics in Edinburgh's cool June climate. I will be attending the 2017 Synthetic Biology 7.0 meeting, which will be the largest ever conference in the field. The conference marks almost exactly ten years of my involvement in synthetic biology as a social scientist. I have decided that my talk at the conference will be my swan song, my farewell to the field.

I did not choose to study synthetic biology. In 2008, my colleagues and I were approached by scientists and engineers at the University of Edinburgh who needed social scientists to be named on their research proposal for a network on standards in synthetic biology. This request appealed to me because I had a strong interest in the changing nature of the life sciences. At the time, I was researching systems biology, a field that grapples with the intimidating complexity of biological systems. Synthetic biology, in contrast, seemed to be an attempt to control this complexity. Also striking was that engineering—as a discipline and an agenda—was being used rhetorically in a way that seemed distinctive.

The proposal for a network in synthetic biology was funded. It was a small sum (in scientific terms at least), but over the next few years it led to my participation in dozens of meetings and conferences, my involvement in much larger research grants, my membership of several policy committees, and most significantly a growing sense of unease about what it was I was meant to be doing. This unease was precipitated by the disparate expectations I confronted about my role in synthetic biology as a science and technology studies (STS) researcher. I found myself continually having to battle expectations that I did bioethics, regulation, or public outreach while attempting to clarify the kind of work that I wanted to be doing, and its value. This book is a consequence of these efforts.

My involvement in synthetic biology was not like anything I had experienced before in my academic work; it was often rewarding but also demanding and sometimes deeply demoralizing. In my previous research on systems biology, I had been in the more traditional social scientific role of the observer: reading scientific articles, interviewing people, watching laboratory practices, participating in stimulating interdisciplinary conversations. I did not have to deal with being conflicted, beguiled, disturbed, upset, loyal or disloyal. In synthetic biology, in contrast, difficult questions quickly arose about the obligations, responsibilities, and challenges of being an entangled social scientist in the field.

A feature of my involvement in synthetic biology from the very beginning was that it was rather exciting. For example, thanks to the synthetic biology network I became part of, I was able to make my first trip to Asia in 2008 to attend a synthetic biology conference in Hong Kong. And synthetic biology has since taken me to places I had never expected to find myself, like the Pinnacles Desert in Western Australia and the World Economic Forum at Davos. This excitement has been accompanied by a feeling of speed and urgency, and something that has struck me is how the temporality of synthetic biology is very different from the temporality of work in the social sciences and humanities, particularly in respect to the different speeds of reading, writing, and publication.

Although my involvement in synthetic biology has often been thrilling, much of it has been uncomfortable, and it is this discomfort that has led me to take stock and reflect on my experiences. I have also increasingly come to realize that the thrill and the speed and the discomfort go together, and that I actively seek out this constellation. Any social scientist who has done ethnographic work will find resonances with what I am describing here, and many will have experienced the affective dimensions of fieldwork. But I do think that there are some features of my involvement in synthetic biology that are significant if not distinctive: being invited to collaborate and being paid to do so.

One of the unusual things about my initial engagements in synthetic biology is that there was a reversal of the normal manner in which social scientists approach those they study. Rather than contacting the scientists and engineers and asking for access to study them and their science, I found myself on the receiving end of emails and phone calls inviting me to be part of synthetic biology research grants. These invitations continued over time, and the amount of money available steadily increased.

Between 2008 and 2016, the UK public sector invested approximately £300 million into synthetic biology (SBLC 2016b), and I have benefited directly from this funding. This inevitably informs my engagements with the field: my hands are dirty. It also means that the stakes are higher than they might be in other social scientific research contexts. I am not funded to study the scientists or to do a laboratory study in an ethnographic manner. I am funded to collaborate with synthetic biologists.

Since 2008, I have found myself more and more implicated, more and more involved, in my object of study. And perhaps because of this, I have shifted from doing research that is primarily observational and descriptive to research that is more explicitly collaborative and, in some situations, interventionist. This reflects changes occurring across the field of STS, so I am hopeful there is value in my attempts to turn my messy and tumultuous experiences into something that has relevance beyond myself, something of methodological and epistemic interest.

BROADER TRENDS

I have given a personal story so far, but the same story could be told in terms of broader socio economic trends. The most important of these is that in industrialized societies around the world, science, technology, engineering, and medicine are considered to be the engines of future economic growth and are therefore priorities for government investment. To obtain funding, it is becoming increasingly common for social scientists to become partners on scientific research projects (Felt 2014).

From my earliest involvements in synthetic biology, particularly strong promissory arguments were made that it would contribute to economic growth and job creation (Royal Academy of Engineering 2009). Synthetic biology has been presented as having the potential to be the technology of this century, underlying a transition from a petroleum-based economy to a bio-based one (Carlson 2010). In the UK, it was included among the "Eight Great Technologies" (Willetts 2013) that would be crucial to ensuring the future prosperity of the country. And the UK's former chancellor proclaimed that synthetic biology would "heal us, heat us and feed us" (Osborne 2012). Similar arguments have led to high levels of investment in synthetic biology in developed nations across the globe (Oldham, Hall, and Burton 2012).[1] What is most significant about these developments for my purposes is that policymakers, funders, and scientists have concluded that a field of such potentially huge significance requires attention from the social sciences and humanities. Expertise in ethical, legal, and social implications (ELSI) is perceived to be needed to address the (nonscientific) "issues" that might arise.

I will explore the constraints of this ELSI framing in more depth in other chapters, but for now I will just note that it has a long trajectory. Work under the ELSI heading was initially funded as a strand of the Human Genome Project in the 1990s, receiving 3 to 5 percent of the total funding (Fisher 2005). And in Europe, controversies over genetically modified food have meant that it has become common for policymakers to involve ethicists and social scientists in the development of potentially contentious technological areas. Ana Viseu (2015, 643) argues that we are seeing the integration of social scientists into scientific research becoming mainstream, "slowly becoming a preferred policy tool for the study and management of science and its relations with society." Those who call for ELSI expertise often do not nuance this call or discriminate between the different types of scholars who can provide such expertise. It is perhaps not surprising that researchers in the field of STS, who are keenly interested in learning about particular areas of science and technology and value access to research subjects highly, respond to these calls, even if such calls do not fit perfectly with their research interests.

In recent years, such ELSI programs have become associated with fields like nanotechnology, stem cell research, and neuroscience. This means that social scientists, lawyers, bioethicists, policymakers, and publics have been increasingly involved in the governance of emerging technologies. Andrew Webster (2007, 463) argues that these fields create "new relations of nature, culture and technology" and provide spaces for intervention, which in turn create openings for researchers from the social sciences and humanities to become co-constructors of scientific fields. Alongside this positive potential, however, there is a danger that they become drawn into a "service" role, with pressures to produce deliverables for grants according to externally imposed agendas, often with the assumption that they will facilitate public acceptance of the technology and help it go to market (Barry, Born, and Weszkalnys 2008). Challenging questions arise about the autonomy of social scientists in an environment where there are different, sometimes conflicting views about the roles they should be playing.

It was not because of my interests in the changing epistemic cultures of the life sciences that I was invited to become part of synthetic biology. My involvement can be interpreted as a consequence of broader policy trends. The differences between my reasons for being involved in the field (access to research sites and interest in the topic) and those of the scientists, engineers, and policymakers who invited me to be part of it (dealing with the ethical, legal, and social implications) are key to my ongoing discomfort, and these tensions recur in the chapters that follow. Many STS researchers, including me, do not want to deliver ELSI research in the way many scientists and engineers understand it. We are often uncomfortably placed in the embedded situations in which we find ourselves.

WHY ROOMS?

The strategy that I have found most useful in making sense of the sometimes-bewildering diversity of my experiences in synthetic biology is to think in terms of the different rooms I have occupied. Over the last decade, I have spent time in various spaces, including large anonymous conference rooms, classrooms in need of a coat of paint, buildings dedicated to bioethics, esoteric laboratories for artistic research, glass-walled government meeting rooms, artisan coffeehouses, and high-ceilinged libraries. Each of the chapters of this book focuses on a different room. Although I draw on my specific experiences in particular rooms, my aim is to consider *types* of room in a more general sense, because I want to be able to speak broadly to other social scientists about the places in which they may find themselves. Some of these rooms are familiar locations for STS research (like the classroom and the conference room), but others are perhaps less so (such as the art studio and the coffee room).

Because of my interest in the changing place of the social scientist in the current funding climate, it may seem more natural for me to talk about roles rather than rooms. I have chosen rooms because they provide a useful means (i.e., a physically and temporally bounded space) to explore what happens when STS collides with other disciplines or sets of expectations such as bioethics, policy, art and design, and science and engineering themselves. Inspired by Webster's (2007) discussion of "social science in the policy room," I expand my analysis to a range of other spaces to show how different rooms contain associations, expectations, and norms, all of which provide a backdrop that allows the distinctiveness of an STS approach to stand out more clearly. It is through these contrasts—these similarities and differences—that I attempt to arrive at an articulation of the type of embedded STS I aim to do.

There is obviously a close relationship between rooms and roles. David Livingstone (2003, 183), who has written extensively on the importance of place in science, explains: "We can plausibly say that someone is 'a different person' at home, in the office, on the playing field, and so on. This is because we define ourselves by reference to the positions—the moral and social spaces—from which we speak." In other words, "*where* we are matters a good deal in trying to figure out *who* we are" (italics in original). Although roles and rooms are clearly not easily separable, I choose rooms (in the plural) because they allow me to think in terms of moving about, changing vantage point, and getting a different perspective in a way that "roles" does not. This ability to change one's location—to embrace multi-sitedness—is one of the most important reasons why I have chosen to focus on rooms.

The idea of rooms is, of course, a conceit, and it cannot capture everything I intend to cover here, but it is a useful one because it can be metaphorically generative. Rooms have a discipline to them. They constrain but also enable certain behaviors—there are clearly things one can do in a bathroom that one cannot do in a dining room. To give an example that I will return to later, getting entry to a policy room (or even just "getting your foot in the door") can allow particular types of intervention. Rooms also usually contain a limited number of people who understand the rules and interpretative frameworks guiding possible interactions.[2] And once one is in a room, certain activities and objects are brought to salience and attention (Kelly and Lezaun 2017).

Once we start talking about rooms, we start talking about space and place, topics that have been central to work in geography for many years. My main intention here is not to further these conceptual discussions but rather to show how rooms provide useful ways of revealing different aspects of social scientific engagement with synthetic biology. Although I use the words "space" and "place" in a nontechnical sense in the pages that follow, I do think it is helpful to note a commonly made distinction between them in the geographical literature. "Space" is often thought of as an abstract, general concept referring to an area in which things can be positioned, while "place" is a specific and meaningful segment of space "that is at once physical and historical, social and cultural" (Casey 2001, 683; see also Agnew 2011 and Cresswell 2014). Thomas Gieryn (2000, 466) argues that places have three defining features: "location, material form and meaningfulness."[3] According to this framework, a place necessarily has a position and a physicality; it "brings people together in bodily co-presence" (Gieryn 2000, 476), but places are also invested with meaning and value and connected to certain experiences, narratives, and practices (Cresswell 2014).

Although there is little discussion of rooms specifically in this literature, it seems appropriate to conclude that a room is a subset of place and refers to an area that is in a building, enclosed by walls, a floor, and a ceiling, with a particular means of entering and exiting. As the *Oxford English Dictionary* (OED) notes, rooms are often set aside for a particular purpose, which can be indicated by a modifying word (such as bed-, bath-, box-, dark-, or ante-). However, as all English speakers know, there is another meaning to the word "room," which the OED defines as "opportunity, scope, or opening for something, by which it is rendered possible." Making room can involve creating a space for actions or events. An advantage of the word "room" is that it has both these meanings.[4]

When one thinks of physical rooms, one often thinks of domesticity and intimacy, but I am not focusing on private, domestic spaces here.[5] I am less interested in spaces where I am alone than those where I interact with others—primarily scientists and engineers, but also, for example, policymakers, bioethicists, and undergraduates. But this does not mean that I am only talking about public spaces. Most of the rooms I discuss are not completely open. There are barriers to entry—to get in takes effort or an invitation. As others have argued, there is not a clear distinction between public and private spaces (Lohan 2000), and many—perhaps most—rooms blur the divide. From a small office in Edinburgh to a convention center in Boston that seats 5,000, sharing a room with someone always involves some kind of intimacy, some kind of temporally simultaneous shared experience.

When sociologists, historians, and geographers do write about science and rooms, it is almost always on the topic of the places where scientific knowledge is made (for an overview, see Henke and Gieryn 2008). Steven Shapin (1988), for example, famously describes the kind of deportment that was appropriate in the rooms where experiments were carried out in seventeenth-century England. Only a visitor to a gentleman's chamber of the requisite social status could provide the appropriate testimony that an experiment was a legitimate contribution to knowledge. My aim here is different, however. I am not conducting a study of the production of synthetic biological knowledge in various contexts. Instead, I am interested in understanding these rooms as places of social scientific observation, collaboration, and intervention.

Rooms have particular features. Because they are bounded places with associated norms and expectations, talk in one room is not the same as talk in another. For example, in a closed meeting room with like-minded colleagues, synthetic biologists will often express their skepticism about some of the ambitions of their field. As a social scientist and a participant in these discussions, can I take these concerns and present them in a completely different context, such as a public talk? To what extent is it necessary to respect the often-implicit rules of different spaces, not only for personal or ethical reasons but also to ensure continued access to ethnographically rich spaces in the future?

This draws attention to another important characteristic of rooms: They are places where power and control are exercised. To avoid being excluded from a room, it might be necessary to restrain one's critical voice. It may not be possible to challenge dominant frames from within certain rooms (and challenging the frames is something that STS values highly, as I will explore in the chapters that follow). So if we do have critical interventions to make, is inserting ourselves into these disciplined spaces really the best strategy? To shift again to the metaphorical—can we be in a room and pull the walls down on top of ourselves, or do we have to be outside to knock down the building? This leads to long-standing questions in the social sciences: Do we need distance to critique? Or does that distance actually prevent us from understanding the realities of the situation and producing an appropriately targeted intervention?

These questions take on an added resonance in the light of feminist work on positionality and marginality, which shows how "knowledge claims are always socially situated" (Harding 1992, 442). A consequence of this is that once we enter a space, we may take on board its norms and limitations—in other words, we can become domesticated by it. This is sometimes a good reason not to enter a room in the first place. Nevertheless, I chose to enter all the rooms described here, and although there is a danger that my critical faculty may have become tarnished, one strategy I have adopted to try to avoid this is moving around. This is why I talk about rooms in the plural.

WORK FLOORS AND MULTI-SITED ETHNOGRAPHY

The importance of moving around is discussed by other social scientists who have conceptualized their work in terms of places or sites. Erik Fisher and Arie Rip, STS scholars who have worked in nanotechnology, describe the range of "work floors" in which they operate, including "research laboratories, conferences, workshops, agenda setting and planning meetings, roadmapping events, and public debates" (Fisher and Rip 2013, 176). They say that a corollary of finding oneself in these different locations is that it is necessary "to move about, observe and actively circulate in locations where actors are shaping the emerging paths of technology and how it will become embedded in society" (176). It is also argued that moving between these different work floors is a strategy for retaining independence, as is moving in and out of the world of nanotechnology (Rip and Robinson 2013) and thus becoming a spokesperson for the "outside" (Rip 2006b).

As another theoretical reference point, George Marcus's exploration of the notion of multi-sited ethnography captures much of my methodological strategy. He defines multi-sited ethnography as "a constantly mobile, recalibrating practice of positioning in terms of the ethnographer's shifting affinities for, affiliations with, as well as alienations from, those with whom he or she interacts at different sites" (Marcus 1995, 113). Movement is key to this definition. A consequence of ethnographic multi-sitedness is that relationships with research subjects become more ambiguous since they change as the researcher moves from site to site, with relationships of power and relative status constantly shifting (Hine 2007). Sometimes the ethnographer will personally identify with those in certain sites, and this identification will "immediately locate the ethnographer within the terrain being mapped and reconfigure any kind of methodological discussion that presumes a perspective from above or 'nowhere'" (Marcus 1995, 112). The impossibility of being "a detached anthropological scholar" in multi-sited work means, according to Marcus, that it is necessary to become instead "a sort of ethnographer-activist, renegotiating identities in different sites" (113). In fact, one of the features of multi-sited ethnography that I find most significant for my own work is that it has normative consequences: it leads to critique.

This is because moving between rooms, and in the process adopting different positions and affiliations, gives one "the ability to articulate alternatives," as David Hess (2001, 242) puts it. The process of moving into and out of a collaborative situation (and from one room to another) gives one a distinctive, critical perspective on a field of study. To express this differently, we know things could be otherwise because we see things being otherwise. For this reason, a certain kind of normativity could be said to derive *from* multi-sitedness. And this not only gives the ethnographer a normative perspective but also, and more actively, "the ability to intervene" (Hine 2007, 662).

THE TWO STRANDS OF SCIENCE AND TECHNOLOGY STUDIES

Where does intervention fit with the project of STS, the rather amorphous and ill-defined field I associate myself with? Perhaps it is because STS *is* amorphous and ill-defined that there has been a great deal of reflection on the nature of the field, its origins, and its objectives. Much of this literature distinguishes between two strands of STS. The first is STS as a normative, activist, interventionist pursuit (Sismondo 2008). Many programs in STS originally came about because scientists and engineers in the 1960s were concerned about the social impacts of their work (often in the context of nuclear power or environmental pollution) and decided they needed to engage with social and philosophical issues as well as technical ones (Zuiderent-Jerak 2015). Arie Rip and Egbert Boeker (1975) give an account of this type of work in the Netherlands, and Sheila Jasanoff (2010) has an American version of this story, grounded in the work of scholars like Dorothy Nelkin. She describes this strand of STS as being concerned with the impacts and control of science.

The second strand of STS is described as the study of the nature and practice of science (Jasanoff 2010). This academic strand of STS originally developed as a response to work in the philosophy of science, which early STS scholars saw as not adequately attending to the realities of scientific practice. Work in this strand contributed much to our understanding of how science is actually done. More significantly, it drew the radical conclusion that "'social factors' counted not as contaminants but as constitutive of the very idea of scientific knowledge" (Shapin 1995, 297). The importance of this refusal to separate the social and the scientific is a theme I return to in later chapters.

Notwithstanding these challenging conclusions, work in this strand typically adopts an observational, analytical stance, often drawing on historical case studies. It does not wrestle with what it means to collaborate or to intervene in science and technology. Jasanoff (1999, 64) even goes as far as to argue that work in this strand led to what she describes as "the inward turn in STS," which led to "a loss of connection with the scientific, engineering and policy communities" (62).

Having stressed my engaged stance in the sections above, it may seem obvious that I should locate myself in the first strand of STS. But, as I have discussed, my interests in synthetic biology initially fitted firmly into the second "academic" strand. I first entered the field wanting to do a much more traditional, observational type of science studies. However, I have changed. Or perhaps I should say that synthetic biology has changed me. I have shifted from observational to more collaborative and interventionist positions.

Synthetic biology changed me because once I started working in the field, I had to quickly revisit STS work on public engagement and governance, since these were topics the synthetic biologists expected me to know about. Although I was already familiar with some of this literature, it took on a vitality and relevance it had not had before because I could apply it directly to my newly engaged work. I also had to acquire passable knowledge of biosafety and biosecurity. This pushed me into areas that I would not have ventured into on my own, and sometimes it seems that I have invested in learning about these topics as a service to the synthetic biologists I work with. It may be that I have become something that they wanted me to be (or that I imagined they wanted me to be) and that this on occasion has diverted me from my own research path. In fact, one of the ongoing issues that I face is trying to work out what the synthetic biologists actually do want of me. Which demands do I accept and resist, and which are not real demands at all? It is my negotiation of these demands imposed on me—by others and by myself—that has led me to attempt to make sense of the position in which I have found myself.

Even after my experiences in synthetic biology, I find that I still do not place myself squarely in the activist strand of STS. Instead, like many other STS researchers, I aim to contribute to both traditions (see Sismondo 2008). To quote STS scholar Lucy Suchman (2014), I want "to combine theoretically informed, scholarly analysis with critical, transformative interventions within technoscientific worlds." I also want to show, in agreement with Rip

(1999, 76), that it is not necessary to choose between “distantiated scholarship *versus* engaged action” (emphasis in original) because in moving from site to site, one will be engaged in different ways in different circumstances. And I aim not only to move beyond the academic/activist divide but also to show the connections between work in these two strands by deriving the normativity of one from the other.

I expand on this aim in later chapters, where I also explore the notion of normativity in more depth. To give a brief explanation here, my intention is to show that the sensitivities of the more academic strand of STS that arise from a close study of scientific knowledge and practices—that is, sensitivities to the contingency of knowledge claims and to the assumptions that frame them—lead to the insight that “things could be otherwise,” that science does not have to be the way it currently is. This is the same insight that is provided by multi-sitedness, as noted above: By moving around, we become aware of alternatives. This may appear to be merely an observation, but I think it is the beginning of something more normative because (to paraphrase Wynne 1993) once we identify the contingency of our commitments, we render them open to change. So we do not have to be engaged in explicitly political or activist work to already be part of a normative endeavor; we may find ourselves participating in this type of work without perhaps even intending to. Even if we do not take active steps to change things “for the better,” we have nevertheless shown that things can be different, and this is potentially emancipatory.

This is a brief account of what I aim to demonstrate in the following pages. But rather than adopting the terminology of “academic” and “activist,” I choose to focus on three different orientations for STS engagement with science and engineering: observation, intervention, and collaboration. Moving from room to room in the following chapters enables me to explore the various situations that allow for each of these orientations, the opportunities they provide, and the challenges they present. Focusing on collaboration and intervention allows me to throw analytical light on both, which, as I have shown, have become increasingly significant in my work in synthetic biology and, I would argue, in STS more generally. This also allows me to link to recent anthropological work, which argues that the norms of traditional participant observation are being challenged by new opportunities and imperatives for collaborative and interventionist work (Marcus 2013; Sanchez-Criado and Estalella 2017). I am aware that there is much discussion in this literature of the nature of "participant observation" as a methodology that "captures the ambivalence of distance and familiarity" (Atkinson and Hammersley 1998, 256) and that, for some (Ingold 2014), is inherently collaborative. To help me distinguish my three orientations from each other, I use the term "observation" rather than "participant observation" throughout, although, as I will show in the chapters that follow, the boundaries between observation, collaboration, and intervention are often blurred, and at times they collapse into one another.

ON WRITING A BOOK

Doing work that is interventionist and collaborative raises questions about how and what to publish (or whether to publish at all, for that matter). The single-authored monograph belongs very much to the academic strand of STS, often based on detached observational work, while a collaborative or interventionist approach can result in more diverse kinds of output—if one's work is collaborative, one's outputs are more likely to be collaborative. In chapter 8, on the ivory tower, I will reflect further on the tensions involved in attempting to do collaborative and interventionist research while fitting into the structures of the academy. For the moment, I will note that there are many features of this type of work that militate against the single-authored monograph—considered from some disciplinary perspectives to be the pinnacle of academic achievement. For a start, I regard the scientists, engineers, and others that I work with as epistemic partners—as those I think *with*—which belies the idea that I can produce the epistemically authoritative account of our interactions. Also, active involvement with a field that is not one's own means continually having to engage with audiences that are not one's disciplinary peers, which means it becomes necessary to learn to express oneself in multiple registers rather than repeatedly honing learned texts aimed at a group of like-minded colleagues.

Aside from these complexities arising from close engagement with scientists and engineers, there is also the issue of collaboration *within* STS. Almost everything I present in the following pages was crucially dependent on working with a few close STS collaborators and owes much to a supportive community of STS scholars in the UK and beyond who have collaborated with synthetic biologists, and each other, over a number of years (see Balmer et al. 2015 for an example of one of our joint outputs). And my conceptually significant interactions have extended beyond STS—notably, I have benefited a great deal from thinking with critical designers and artists. These debts are much more than acknowledgments; they are methodologically and epistemically significant. Importantly, going into many of the rooms alone is much more perilous than going in with a companion. I have done both, and I know that working with a trusted colleague at my side has emboldened me to do far more than I would have done on my own, as well as provided an invaluable opportunity to share reflections and insights and to develop analyses. Of course, many would agree that all knowledge is made in some kind of conversation with others, whether these others are spatially and temporally simultaneous or not. I think my collaborations with my STS colleagues are significant on a different scale, however, to such an extent that I am aware that it would be both hypocritical and hubristic of me to present our joint work as my own. But I am subject to the pressures of the academy, and I see the opportunities allowed by a longer single-authored text, so I have decided to adopt this traditional form of the academic monograph when it is, quite frankly, both inadequate and misrepresentative of collaborative endeavor.

There are other reasons why I have chosen this particular written form. When I first became involved in synthetic biology, I struggled to find literature that I could draw on to make sense of my experiences. As I have described, I was not doing a straightforward laboratory ethnography because I was receiving money from scientific research grants and there were determinate expectations about my role and contributions to the scientific work. But I was not doing predefined consultancy or short-term contract research work either. I had a significant amount of autonomy and was keen to make academic contributions to the social, philosophical, and policy dimensions of synthetic biology. I felt a need to write for researchers (often early-career researchers) from the social sciences and humanities who find themselves attached to scientific research grants, centers, and programs and who are expected to deliver to external agendas while simultaneously producing work that they and their peers find valuable. There are STS researchers who want to collaborate and intervene but are left with questions about how to do so. Is it possible, for instance, to be embedded in a new scientific field without "selling out"? Can one be an analyst of such a community without becoming a handmaiden to it? And what constitutes good work in these contexts?

My final comment on form is to note that I have chosen to write a first-person account. This is admittedly a risky strategy that is likely to be perceived as inadequately academic by some. But it seems inauthentic to discuss collaborative and interventionist research in any other way, to write as if I was solely a detached observer. By writing in the first person, I am emboldened by arguments from other STS researchers that "not often enough do we embrace ourselves as subject matter within our own discursive exercises" (Roberts 2010, 116; see also Croissant 1999) and by feminist scholars who maintain that knowledge is always situated and inseparable from experience (Haraway 1988; Lohan 2000; Stanley 1993). Furthermore, STS has the advantage of not being a discipline whose boundaries and modes of expression are heavily policed. It is an interdisciplinary field that provides more scope to experiment with less conventional rhetorical forms than established disciplines (e.g., see Ashmore, Myers, and Potter 1994; Mol 2002), so I embrace this opportunity here. Although I adopt this form, it is significant that my experiences are not unique; I see resonances with the activities of many other STS researchers, and I connect my account throughout to relevant social scientific work. My aim is that this book will be a companion for the engaged STS researcher, whatever their particular field or focus of study.

A TOUR OF THE ROOMS

I now give a quick tour of the different rooms found in the following chapters. I start close to synthetic biology in the laboratory and the conference room. I then shift to the more neutral territory of the classroom and the coffee room, then on to the art studio—a space that clearly does not belong to synthetic biologists. Next are the bioethics building and the policy room, both of which are formal settings that are separated from the science. The ivory tower, my final room, is a place of retreat and detachment. The chapters are thematically rather than temporally organized, which means that I start near the end of my involvement in synthetic biology in the laboratory and cut across a decade's worth of my participation in the field in the conference room. In each room, I explore opportunities for observation, intervention, and collaboration. Throughout, I draw on synthetic biology as my example and case study, taking advantage of the fact that my early years in the field coincided with its rise in scientific and policy prominence and discussing its distinctive features, possibilities, and limitations. But my primary goal is not to transmit a substantive body of knowledge about the field, so I diverge from most of my previous work on the topic.[6] There is excellent research elsewhere on synthetic biology from the perspectives of the social sciences and humanities (e.g., see Campos 2009; O'Malley 2010; Roosth 2017), yet my aim here is different: to explore what it means to be an engaged and entangled STS researcher.[7]

The first room is the laboratory, which is an important place for STS because "laboratory studies" was significant in the birth of the field. Although STS researchers often start their investigations in the laboratory, this was not the case for me, since the laboratory was not a room I was invited into. In fact, it took me several years to make my way there. Laboratories are protected spaces that belong to scientists, and one enters them as a guest. Once I did spend time in a synthetic biology laboratory in Edinburgh, I found it largely indistinguishable from other laboratories in molecular biology, but its aims and aspirations were different. The scientists were building a synthetic yeast and attempting to apply engineering principles to this complex and somewhat recalcitrant organism. I show in chapter 1 how my orientation in the laboratory was primarily one of observation rather than intervention or collaboration. I was methodologically constrained in this space, partially because of the obligations I felt toward the PhD students and postdocs who patiently hosted me. I argue that because of these constraints, and because of the importance of social, political, and economic forces in the making of a scientific field, it can be valuable to move beyond the lab.

The next room is the conference room, a site that was very important for my involvement in synthetic biology. It was this room that made me decide it was worth investing my time in the field, because in it I found a group that was open, interdisciplinary, and committed to community-building. A great deal of my fieldwork has been done in these privileged, sometimes thrilling sites. I was rarely a passive audience member at synthetic biology conferences, however. The price I had to pay for attendance was usually to give a talk, often in response to a vague request that something "social" or "ethical" be covered. Negotiating these requests while simultaneously trying to give a presentation that furthered my own academic interests was an ongoing challenge. In chapter 2, I focus on four synthetic biology conferences known as the SBX.0 conference series, which took place in Hong Kong, Stanford, London, and Singapore between 2008 and 2017. This allows me to sweep across nearly a decade's worth of my involvement in synthetic biology and address the changes I saw in the field. I assumed an active role in all four conferences and pursued opportunities for intervention, with mixed results.

I show that this room presents particular challenges because it is a space that belongs to the synthetic biologists and is dominated by scientific, industrial, and political elites. STS researchers can become domesticated by this space if they spend too much time in it. I conclude that to intervene from within the conference room, it is necessary to surrender some critical distance.

The classroom is not a typical fieldsite, but it is a place where many STS scholars spend their time because the teaching of scientists and engineers is often the justification for our academic positions. Synthetic biology is particularly interesting from a pedagogical perspective because of an annual event called the International Genetically Engineered Machine (iGEM) competition, where thousands of undergraduates from around the world compete to build simple devices using synthetic biology. The competition requires that teams do some work in the area of Human Practices, which encompasses a spectrum of social, ethical, legal, and regulatory topics. I first became a Human Practices adviser to the Edinburgh iGEM team in 2008 and was a regular attendee and judge at the competition until 2016. Although this space provided an unparalleled opportunity to engage with future synthetic biologists, the scope was limited for expressing ambivalences and exploring alternatives. Alongside iGEM, I was given the opportunity to develop an STS-inflected ten-week course for synthetic biology master's students. On the basis of these pedagogical experiences, I raise questions about what kinds of knowledge or distinctive insights STS researchers can or should try to introduce through teaching. I argue that the classroom is a place for intervention, but that this intervention is slow, sustained, and incremental. Importantly, one of the features of the classroom is that the hierarchies are very different from those more typical of STS research; instead of "studying up" (Forsythe 1999), in a teaching situation the STS researcher is the one judging and evaluating the student. This draws attention to the conflicting and variable power relations in multi-sited work (Marcus 1995).

A place where power relations are much less apparent is the coffee room, and informal spaces such as coffee shops, pubs, bars, and restaurants are locations where one inevitably spends time when engaged in long-term interdisciplinary working relationships with scientists and engineers. These rooms are to some extent sites for fieldwork and for deepening understanding of the field, but they are also contexts where friendships develop, which highlights the importance of affect in social scientific involvement in scientific worlds. This has methodological consequences because these peer-type relationships and friendships do not easily lend themselves to straightforward distinctions between social scientific researcher and scientific "informant." Instead, the interactions I have had with scientists and engineers have transformed me and forced me to question my own assumptions. In chapter 4, I show how the coffee room lends itself to epistemic partnership and experimental collaboration and how exploring ideas together across disciplines can lead to valuable new understandings, although the opportunities for intervention and critique are limited in this space.

Turning next to the art studio, I discuss my involvement in a project called Synthetic Aesthetics, which brought synthetic biologists together with artists and designers in six paired reciprocal exchanges. This project was not funded through the normal mechanisms but was the result of a weeklong residential event called a "sandpit," in which participants were pushed to develop proposals that were more cross-disciplinary and ambitious than the research that is normally funded through peer review. The project took me to spaces such as Mediamatic, an art and new technology studio in Amsterdam, and SymbioticA, a laboratory for the biological arts in Western Australia, where scientific tools and equipment are repurposed for artistic ends. I initially thought I would play an observational role in the art studio, but I found this increasingly unsatisfactory and instead shifted into the position of a collaborator involved in a shared investigation with the project's artists, designers, and synthetic biologists. In chapter 5, I show how interactions with these groups allowed me to participate in what I call an emergent form of critique, which expands the range of possibilities that can be imagined in synthetic biology.

My next room is actually a building, and it is based on my experiences in the Nuffield Council on Bioethics, which occupies an elegant Georgian townhouse in central London, and the Hastings Center, located in a grand manor house in upstate New York. I was invited into both buildings to participate in working groups and produce reports, on the grounds that I would speak to the ethical dimensions of synthetic biology. These experiences were a reminder that STS researchers do not own the "nonscientific" territory; it also belongs to other groups such as bioethicists and lawyers—groups that tend to be much more explicit about their normativity. In chapter 6, I draw on my experiences in these buildings to attempt to articulate a normative orientation for my work that avoids a division of labor between "facts" and "values" and that is authentic to the sensibilities of STS. Drawing on a term familiar from the STS literature, I call this “otherwising.” I show how otherwising involves demonstrating contingency in scientific and technological developments where necessity is assumed, thereby opening up the possibility for things to be changed. I end by arguing that an advantage of the bioethics building is its separation from the institutions of science and engineering, which gives independence to the interventions made from within this space.

The policy room is a place where STS researchers are increasingly spending their time (Webster 2007). Entering this room provides clear opportunities for interventionist work. In chapter 7, I focus on my involvement in two policy groups. I was on the Bioscience for Society Strategy Advisory Panel for the UK’s Biotechnology and Biological Sciences Research Council for eight years. This multi-stakeholder panel was itinerant, meeting in hired rooms in central London. This group’s role became one of gradually trying to introduce an openness to broader perspectives in the organization against a background of political pressures. The second group, the UK Synthetic Biology Roadmap Coordination Group, was a ministerially appointed committee tasked with producing a report on a tight timescale that led to the release of over a hundred million pounds of funding for synthetic biology. The group was made up of representatives from business, academia, and government. We met every two weeks for eight months in a glass-walled meeting room in London at the UK’s Department for Business, Innovation, and Skills. I was one of the social scientists in the group, and we introduced a chapter on responsible research and innovation (RRI) into the roadmap. However, we failed to integrate STS insights into the rest of the report or to prevent narrow framings of innovation and deficit models of public acceptance. In chapter 7, I explore the challenges of intervention from within the policy room.

My final room is the ivory tower, which is sometimes a very appealing place because it can be difficult to unsettle dominant assumptions in the other rooms, particularly when power and money are involved. It can be tempting to retreat “from lab to library” to avoid the affective entanglements and ongoing discomfort of being an embedded researcher. This is all the more attractive considering that some scholars from the humanities and social sciences make valuable contributions to the literature on synthetic biology without ever spending any time in the more perilous spaces discussed in the other chapters of this book. Another pull of the ivory tower is that this is where we acquire esteem from our peers. Trying to exist inside and outside the ivory tower simultaneously is precarious and can lead to destabilizing critique. Of course, the "ivory tower" is itself historically and culturally specific; it has its own politics, and it is not free of interests (Rip 2014; Shapin 2012). Retreating to it is only a viable option when one has job security, but many social scientists involved in emerging technologies are on temporary short-term contracts. Furthermore, STS has an uneasy relationship with the ivory tower and with disciplinary consolidation more generally, since STS researchers analyze and criticize the power structures that form around knowledge communities. Despite these concerns, I conclude that the ivory tower can be a valuable space to spend time in, as long as one is not a permanent resident there. A temporary visit can provide space for the reflective observation of one's data and experiences, which can expose taken-for-granted assumptions.

After traveling through the various rooms that have marked my involvements in synthetic biology, I conclude that itinerancy is a valuable strategy because moving from room to room reveals the implicit assumptions and distinctive features of each location. I show that observation, collaboration, and intervention can all be appropriate methodological orientations in different rooms and at different times, and that all can provide opportunities for otherwising. I explore the importance of a place for STS for the itinerant researcher—but rather than building a room of our own, I suggest we think of this place as a safe harbor that provides support and replenishment while remaining open to the world. I end by affirming a commitment to a collaborative form of STS: one that extends beyond specific technological fields to work with others in opening up possibilities and bringing alternatives to light.

1 THE LABORATORY

It was only after I had been working in synthetic biology for several years that I got to the laboratory, the site that is normally considered the most important for the social study of science. Inside the laboratory's thick walls, I found junior researchers on short-term contracts, recalcitrant yeast cells, and methodological constraints. I observed the scientists, the engineers, and the yeast, but I did not intervene or collaborate. This chapter describes this experience. I start, however, by exploring the place and significance of laboratory studies in science and technology studies (STS) as well as criticisms of the external positioning and narrow focus it often assumes. I end by arguing that although a laboratory study can be valuable as part of a broader investigation of a field like synthetic biology, there are reasons to move beyond it.

ON BEING IN THE LABORATORY

The importance of the laboratory for STS can hardly be overemphasized. It is the STS fieldsite par excellence. As Christine Hine (2007, 658) puts it, "The laboratory ethnography has a key role in the foundation myth of contemporary sociological approaches to scientific knowledge." It was the rise of "laboratory studies" in the 1970s and 1980s that defined STS as a field. Rather than relying on philosophical or scientific accounts of the distinctive features of science, STS researchers turned to studying the practices of scientific knowledge-making themselves. They went to these "special places from which knowledge emanated" (Doing 2008, 280) and demonstrated the importance of location for the making of science (Law and Mol 2001).

Ethnographic observations from across different laboratories highlighted the diverse local contexts from which the universal claims of science emerged (Knorr Cetina 1995). The detailed descriptions that characterized such ethnographies revealed the considerable labor and negotiation necessary to produce what eventually resulted in published scientific findings (Latour and Woolgar 1986).

Laboratories can be understood as "'bounded spaces' of world construction" (Knorr Cetina 1995). Arie Rip and Pierre-Benoit Joly, for example, describe a laboratory as a "protected space" that "brackets out the outside world" (Rip and Joly 2012, 5). Such "bracketing out" enables scientists to "gain exquisite control over the objects of their analysis" (Gieryn 2006, 5). It allows them to tame what was previously wild and to produce environments "more or less free of the vicissitudes and promiscuities of 'outside'" (Gieryn 2006, 6). This means that efforts need to be made by STS researchers to "penetrate" (Knorr Cetina 1995) the "semi-private spaces of the laboratory" (Garforth 2012, 280) so that they can understand the local and contingent influences on the production of knowledge. Explicit permission to access a laboratory is required, and those from outside have to enter it as visitors and guests (Shapin 1988).

Some have argued that a problem with traditional laboratory studies, despite its established and exalted status, is that it assumes a rather removed, observational mode of engaging with the science. As Hine (2007, 659) notes, laboratory studies "renders a very conventional notion of ethnography to be the appropriate methodology for studying science." There is an emphasis on witnessing that "reifies the figure of a detached and external observer to the action under study" (Bea 2017, 71). Laboratory ethnography typically emphasizes distance and exteriority, which feminist commentators have argued is associated with "domination and mastery" and "the masculine gaze" (Garforth 2012, 269). Although I feel the pull of the laboratory as a place for STS, my predicament, as outlined in the introduction, is that I want to go beyond the type of detached data gathering I am calling "observation" to experiment with intervention and collaboration.

ON NOT BEING IN THE LABORATORY

It is significant that the laboratory was not a place I was invited into in my initial involvements with synthetic biology, although I did make my way there eventually. This was because of expectations about the role I would play in synthetic biology as a social scientist, expectations I discuss further below. More broadly, interacting with scientists and engineers in sites other than the laboratory is a feature of what Hess (2001) calls "second generation" STS ethnography, which extends beyond the laboratory to include other sites and provides opportunities for novel empirical and theoretical work (Beaulieu 2010). Hine (2007) warns that moving beyond the lab in this way risks estrangement from the canonical texts on which contemporary STS is based. Nonetheless, it is notable that the most recent *Handbook of Science and Technology Studies* (Felt et al. 2017)—the key marker of current activity in the field—has no chapter on laboratory studies, in contrast to the two editions that preceded it. This implies that second-generation ethnography is becoming more common.

Another reason not to restrict STS research to the lab is because of its potential to narrow the focus of study. As Jasanoff (2012, 439) has argued, a danger of following scientists and engineers in the laboratory is that one's "horizons are limited to a large extent by the imaginations of the protagonists, who have to varying degrees cloistered themselves and their ways of knowing away from the rest of the world." This highlights what has already been noted above: The lab is a secluded space that intentionally excludes the outside world (Callon, Lascoumes, and Barthe 2009). If one is studying research conducted in the lab, one is almost always studying a project that has already been funded, where the goals have already been set by the scientists and engineers. Such a focus can exclude an analysis of "the political, institutional and economic forces that govern the selection of research fields and programs" (Hess 2001, 236), making it hard to ask questions such as: Why has this research project been funded in preference to other research projects? And why are some research fields (such as synthetic biology) funding priorities in the first place? As Alfred Nordmann (2016) has argued, the laboratory is not necessarily the place where the future is made.

In respect to synthetic biology, another disincentive to go into the lab was that when I first started studying the field, synthetic biologists were not spending much time there themselves. Their efforts were focused on building a new field, and to do this they had to move into other spaces. In the UK, this was intentionally supported by the funding policy because when the research councils first decided to fund synthetic biology in 2008, they determined that it was premature to invest in research and that it would be more useful to try to build a community by supporting networking activities such as meetings and workshops. Laboratories did not seem to be the places that were most relevant for studying these attempts to construct a new discipline.

As noted in the introduction, the University of Edinburgh, where I am based, led one of the seven networks funded by the UK research councils. Its focus was on standards in synthetic biology, and it also involved the Universities of Glasgow, Cambridge, Newcastle, and Imperial College London. There was a requirement from the funders that scholars from the social sciences and humanities were involved in all the networks. This helped to create a community of social scientists with an interest in synthetic biology across the UK and set a precedent for the involvement of researchers from the social sciences and humanities in many of the synthetic biology funding programs that followed. But rather than being funded to do laboratory studies, my social scientific colleagues and I were invited to be part of these networks primarily because the funders wanted us to consider the ethical, legal, and social implications (ELSI) of the field. The constraints of this ELSI framing will be discussed in more depth in chapter 6 on the bioethics building, but for the time being, I will just note that it led to expectations that we work on topics such as biosecurity, bioethics, or regulation and that we would deliver "outreach" events to reassure a supposedly fearful public. None of these activities were assumed to require an in-depth study of what was actually going on in the lab. In fact, the ELSI framing seemed to push us away from the lab.

MY INTERESTS IN SYNTHETIC BIOLOGY

The ELSI framing also did not resonate with what had drawn me to synthetic biology in the first place, which was the field's attempts to reimagine biology as a material that could be reliably and predictably engineered. I was intrigued by much of the early work in the field, which involved programmatic statements about the nature of biology and engineering and the differences between them (see, e.g., Andrianantoandro et al. 2006; Breithaupt 2006; Brent 2004; Endy 2005). For example, Tom Knight, an influential figure in the development of the "parts-based approach" to synthetic biology at the Massachusetts Institute of Technology in the early 2000s (discussed below), is often quoted as saying that while a biologist is delighted with complexity, the engineer's response is: "Damn, how do I get rid of that?" (Hammersley 2009). According to Knight and his colleagues, synthetic biologists should adopt the engineer's approach. This attempt to cast living things as engineerable also involved extensive use of engineering metaphors (Hellsten and Nerlich 2011). To give an example that will become relevant later, the metaphor of a "chassis," drawn from mechanical engineering, started to be used by synthetic biologists to refer to their host cell of choice, encouraging the idea that the cell is a neutral frame into which engineered constructs could be inserted.

My interest was in this clash of epistemic cultures—in the audacity of engineering meeting the complexity of biology and forcing both to change in the process. I was fascinated by the way in which synthetic biologists were "confronted with the complexity and unpredictability of engineering inside living cells" (Cameron, Bashor, and Collins 2014, 381) and how "the hopeful contingencies of biology" (Davies 2011, 439) required humility from the engineers. Getting into the laboratory seemed to be a good way of investigating these topics.

My initial interests were not solely epistemic, however, because as well as building biological things, synthetic biologists were also actively building a community with certain values. And this was not just a community for professional scientists and engineers; there was an attempt to extend it to encompass undergraduates, amateur do-it-yourself biologists, artists, designers, lawyers, bioethicists, and social scientists like me (as will be discussed in chapter 2). Another distinctive feature of the then-dominant parts-based approach to synthetic biology was an attempt to prevent the technology being locked up by patents and other forms of intellectual property rights, an attempt to imagine more distributed and open forms of innovation (Rai and Boyle 2007; Henkel and Maurer 2009). In this way, synthetic biology appeared to set itself against the monopolization of genetic technologies by large corporations that had been prevalent in the past and to raise questions about what biotechnology could be and should be. An investigation of these questions extended beyond the laboratory to encompass other spaces. In summary, I was simultaneously drawn to the lab and wanted to go beyond it.

BECOMING INVOLVED IN RESEARCH GRANTS

All these interests required access to the growing community of synthetic biologists, which is why I was keen to be part of the larger synthetic biology research grants that followed on from the synthetic biology networks. But my

STS colleagues and I repeatedly found that the expectations among scientists and research funders about the role we would play on these grants were rather different from our own. For example, with some social science colleagues at King's College London, I was part of a large, multi-institutional synthetic biology research grant that aimed to create an infrastructure platform for synthetic biology. The grant was written in a rush, as is often the case, and without being consulted, we were allocated a work package called "Innovation, Impact, and Exploitation," where our assumed role was to facilitate the progress of science to market. In the course of getting this grant approved, we changed the title of this work package to "Responsible Innovation, Translation, and Commercialization," making them topics of study rather than things to deliver. We also managed to integrate STS-inflected research on standards, infrastructure development, and intellectual property into the proposal, but there were extensive negotiations and conflicting expectations about our work.

Another grant I was written into—the one that eventually got me into the lab—was associated with an international project to build a synthetic yeast genome. In this case, my Edinburgh-based STS colleague Emma Frow and I were involved from the early stages. We designed our part of the proposal to fit with our epistemic interests in how tensions between engineering and biology in synthetic biology were exhibited in the relationship between rational design and directed evolution in the construction of the synthetic yeast genome. However, the description of our research was not included in the research proposal but instead had to be squeezed into the two-page "ethics" section of the grant, along with the research plans of a bioethicist from a partner institution in the United States and a mandatory description of how the project as a whole would comply with existing regulations.

In this case, we met an obstacle at the review stage when one of the referees, clearly from a scientific background, said that the project demanded "periodic open discussions with the public," something we had not included in our plans. In composing our collective response to the reviewers, some of the scientists in the project team expected us to change our part of the grant to deliver public engagement. We resisted this on the grounds that there was not adequate budget for carrying it out in a meaningful manner. In pushing back in this way, we put the whole grant in jeopardy, although it was ultimately funded as it stood.

Once the research started, this gave me a chance to do a conventional lab study of the synthetic yeast project. But it is notable that I had been studying synthetic biology since 2008, and I only entered the lab as a research site in 2015. I now turn to this laboratory experience, after briefly situating the synthetic yeast project in the broader field of synthetic biology.

THE SYNTHETIC YEAST PROJECT

The parts-based approach to synthetic biology emerged at MIT in the early 2000s and quickly became the field's poster child and the focus of much attention (see Campos 2009; Frow 2013; Roosth 2017). This approach was driven by the aspiration to "make biology easy to engineer" (Endy 2008, 340) by attempting to construct modular, standardized, interchangeable biological parts that could be inserted into recipient cells, where (in theory) they would perform the synthetic biologist's specified function (Andrianantoandro et al. 2006). BioBricks—DNA sequences designed in a standardized format and often analogized to LEGO bricks—were an early instantiation of this approach (see Frow 2013). This type of synthetic biology was pursued by the scientists who were part of the Edinburgh-led synthetic biology standards network, so it was dominant in my early encounters with the field.

Work that is sometimes called "synthetic genomics" or "whole genome engineering" developed alongside the parts-based approach (O'Malley et al. 2008; Smith et al. 2003). Rather than building discrete biological parts, the aim of this approach was to construct complete genomes, and the focus of early efforts was on making synthetic versions of existing viruses (Cello, Paul, and Wimmer 2002) and very small bacteria (Gibson et al. 2008). In 2007, a group led out of Johns Hopkins University in the US decided to embark on the construction of a synthetic version of a genome that was tenfold larger than any previously attempted: that of the familiar yeast species *Saccharomyces cerevisiae* (also known as baker's or brewer's yeast). They chose to completely redesign the yeast in a way that maintained the organism's fitness and stability while increasing the flexibility and manipulability of its genome. This included designing in the capacity to evolve the yeast on demand by inserting so-called "scramble" sites into the genome (Dymond and Boeke 2012). The redesign also required the large-scale removal of much noncoding DNA that did not appear to have any function. This ambitious genome construction project, still in progress at the time of writing, is called *Saccharomyces cerevisiae* 2.0, or "Sc2.0" for short, following the software naming convention that is rife in synthetic biology. Whether Sc2.0 will be considered a new species of yeast remains to be seen, but the synthetic organism certainly challenges ideas of provenance and descent, since it is designed on a computer and made from synthetic DNA.

The Sc2.0 project is internationally distributed, with the 16 yeast chromosomes being synthesized in nine different locations across four continents (Pretorius and Boeke 2018). Emma Frow and I were included in a grant associated with the project because two of the chromosomes were being synthesized at Edinburgh. A laboratory study had not been written into the grant, but the principal investigator (PI), a synthetic biologist, was happy to accommodate our desire to do one. By the time the grant was funded, Emma Frow had moved to a different university and Erika Szymanski joined me on the project. Rather than relocating to the lab full-time, we decided to spend one to two days a week there while retaining our primary home in our STS department, a decision that will be reflected on below. I adopted this strategy for eight months (from October 2015 to May 2016), and Erika continued for a further 12 months. I primarily draw on my own experiences here, but discussions and collaborations with Erika have been very influential on my thinking.

Although it felt like an achievement to finally start a lab study, for the days I was there, I did not spend all of my time literally in the lab. I was given desk space in one of two rather cramped and cluttered offices, which I shared with three PhD students and a postdoc. These offices were part of a cluster of four interconnected rooms, the other two being the PI's office and the lab itself, which looked very much like a standard molecular biology laboratory with benches, freezers, and incubators. I spent the majority of my time in the shared office, as did the postdocs and PhD students, and this is where most of their conversations happened as well as the work of analyzing results, planning experiments, and preparing presentations and papers. The laboratory was rather small, so it was not a space to occupy unless one had something specific to do, and when I was there, I was aware that I was often getting in the way of others. On some days, I did not go into the lab at all but stayed in the office, joining in the discussions, having scientific posters on the wall explained to me, or being shown images on computer screens. One of the students was doing a computational PhD and did not work in the lab herself, but that made her work no less interesting to me. Another relevant room was the canteen, where conversations continued over lunch. This all shows that even when one is doing a laboratory study, one is not solely based in the lab.

This laboratory, like most laboratories in the biological sciences, was a place for early-career researchers—PhD students and postdocs—who spent much of their time grappling with experiments that did not work as planned and dealing with financial and career insecurities. It was these PhD students and postdocs whose work I followed. They would call me from the office to the lab when they thought that something would interest me and they patiently explained to me what they were doing and why. Some of them had only recently started lab work themselves, others were several years into their PhDs, still others were experienced postdocs, moving from lab to lab on short-term contracts with no particular commitment to synthetic biology. They all generously gave me their time, and I was dependent on their hospitality. This put me in a relationship of obligation to them, which had consequences—it limited the extent to which I felt I could or should intervene in what they were doing.

The synthetic yeast lab itself was not exceptional. It was indistinguishable from other laboratories in molecular biology, and the techniques used were very similar. But one of the PhD students who split her time between this lab and a more traditional yeast genetics lab told me how she thought the two were very different, despite looking the same. This was because of the engineering orientation of the synthetic yeast lab, as demonstrated by its guiding aspiration to build a completely novel genome.

What I was struck by was the ways in which this engineering project was forced to engage with idiosyncratic objects in the lab—both physical and biological. For example, in a manner that did not seem to resemble rational engineering, the gels used in almost every experiment to separate and visualize DNA strands of different lengths had to be made each time they were required by the rather messy process of dissolving agarose powder in water in a microwave and pouring the resulting viscous liquid into molds. My field notes also include observations about the particular equipment used when working with yeast, such as the sterilized black velvet used for yeast mating and the glass beads that were necessary to roll the yeast on agar plates.

The scientists often drew my attention to the qualities of the yeast itself, such as its tough, thick cell walls, which required boiling to break down, as well as its distinctive smell, reminiscent of baking bread. They praised it for its speed of growth and tolerance to manipulation. But their discussion of yeast went beyond its physical qualities; many of the scientists expressed affection for this particular organism on which they had honed their specialist skills. Rather than treating it merely as an object, they carefully attended to it and appreciated its idiosyncrasies. They often linked their affection to *Saccharomyces cerevisiae*'s everyday familiarity because of its role in making bread and beer. And the project overall aimed to preserve the "yeastiness" of the yeast (Urquhart 2014), even in its synthetic form. "Yeastiness" does not fit particularly well with an engineering mentality that treats a biological cell as a neutral "chassis," and it is an example of how working with biology often requires that the engineering aspirations of synthetic biology are attenuated (Calvert and Szymanski 2020).

After I had been going to the lab for about a month, one of the postdocs was keen that I get my "hands dirty" and also get a sense of the responsibility for and difficulty of carrying out an experiment successfully. He set up a miniprep for me to do—a common method of extracting and purifying a desired sequence of DNA from a circular plasmid, which required several steps involving pipetting, centrifuging, and filtering.[1] Attired in purple plastic gloves and a blue lab coat (which made me stand out because the others did not habitually wear them), I followed the protocol with the postdoc's guidance. After several hours—far longer than the procedure normally took—I ended up with a reasonably pure sample of the desired DNA. This was not a particularly significant experience for me; nothing rested on the success of my miniprep, as it would have if it was part of an experiment I had designed. It did not make me want to retrain as a scientist, and it was not my most extensive laboratory experience. (I took part in a synthetic yeast summer school six months later that involved many hours of laboratory work.) But this miniprep seemed to be meaningful for the synthetic biologists at Edinburgh. Unbeknownst to me, one PhD student tweeted about it, and another PI at Edinburgh said that she was disappointed I had not chosen to do my first miniprep in her lab. During a panel at a synthetic yeast conference the following summer, the PI felt it was necessary to tell the plenary audience about my miniprep. It seemed to give me added legitimacy and perhaps presented me as more of an insider to the project than an external observer.

OUR RESEARCH TOPICS

Overall, there were few expectations concerning the role that we, the social scientists, would play in the project. The fact that we had to force a very short description of our planned activities into the two-page ethics section actually resulted in a situation where we had considerable freedom to pursue topics that emerged from our investigation of the laboratory work. It is also significant that at the proposal stage, Emma Frow and I were written in as co-investigators on the grant and not positioned as working under a scientific PI.

This meant that when we got into the laboratory, Erika and I could tackle questions that interested us, such as the relationship between building a genome and understanding it, the difference between engineering a whole genome and engineering discrete biological parts, and the extent to which the characteristics of the organism (its "yeastiness") was important to the project. As we had outlined in our section of the proposal, we also explored the relationship between evolution and design by looking at how evolution and randomness were incorporated into the project as part of the "scramble" system (Szymanski and Calvert 2018). This tied back to my overarching interest in the ways in which the distinctive characteristics of biological systems often do not align with the engineering goals of synthetic biology. A scientist working on the synthetic yeast project made this point (rather beautifully) at a synthetic biology conference in 2017 when she said: "We are not the architects of genomes. We lack subtlety or grace; we must leverage humility and luck" (Richardson 2017).

So rather than dealing with the social and ethical "implications" of the project, we investigated the topics that emerged from our study of the laboratory work (and would not have emerged had we not spent time in the lab). We managed to do this without accepting a separation between the scientific and the social issues—a separation that is often asserted or assumed and will be discussed further in chapter 6, on the bioethics building. We engaged with the same topics that interested the scientists and engineers but saw them slightly differently. These divergent disciplinary perspectives provided us with different lenses on the same phenomena, rather than carving out separate territories of expertise.

NORMATIVITY AND MODULATION

This work was enjoyable, but it could not be described as interventionist or collaborative. Although I had many interesting discussions in the laboratory, I did not try to be explicitly normative or directive in this context. This was partly because of my positioning: I was there to learn more about the project, the experiments, the laboratory techniques, and the theories behind them. I was in this sense a kind of student or apprentice and, as noted above, totally dependent on the time and hospitality of the members of the lab. I did not feel that I could or should challenge the goals of the research project or the manner in which it was being pursued.

The question of the extent to which social science and humanities researchers can influence research in a laboratory context has been addressed by STS researchers, some of whom have introduced the concept of "midstream modulation" (Fisher, Mitcham, and Mahajan 2006). "Midstream" refers to a stage of research and development that lies between "upstream" science policy and "downstream" products. Fisher and colleagues (2006, 492) define midstream modulation as "integrating societal considerations into an academic research laboratory setting." I find this definition somewhat problematic because of the implicit assumption that societal considerations are separate from academic research. However, I do find discussions of midstream modulation useful because the emphasis on *modulation* recognizes the difficulties of actively intervening at the laboratory level. Rip (2006a, 85), for example, argues that the "quasi-autonomous dynamics" of laboratory science "appear to be so strong that governance actors cannot do much more than try to modulate what is going on anyway." Such modulation increases the "reflexive awareness" of scientists and engineers rather than changing their research trajectories. And this is not even something that has to be done intentionally. Rip and Robinson (2013) maintain that just being in the laboratory as a social scientific researcher will in itself increase reflexivity, even if this is not the aim.

To be honest, I am not sure what effects my presence had in the lab, apart from demonstrating to the scientists and engineers the existence of researchers in STS. But I do not conclude that my time there was a failure or a missed opportunity. When I was in the lab, neither intervention nor collaboration seemed appropriate, but observation did. And one of the most significant things I observed was the scientists' observations of the yeast, which they observed with affection and attentive care.[2] Indeed, "attentive care" is one of the definitions of the Latin route of observation, which can itself be defined as "the careful watching and noting of an object or phenomenon" (OED). Being in the lab gave me an opportunity to learn from the scientists' observation of the yeast and attempt to engage in a kind of observation that was more than detached data gathering. Observing scientists in their work requires attending to and giving oneself to their activities for a discrete period of time, subjugating one's own interests to theirs. Although observation can undoubtedly be objectifying, I hope that I learned from the scientists' own observations to observe them in a way that was not.

Despite involving a degree of voluntary subjugation, I must also admit that adopting the position of the observer in the lab was rather a comfortable position to be in. This was in contrast to the discomfort I felt in many of the other rooms that are described in this book—discomfort that provoked reflection and analysis. My experiences in these other rooms preceded my time in the laboratory, leading me to sometimes describe myself as "retreating" to a more traditional laboratory study, enjoying the protection provided by its walls.

IS THE LABORATORY A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES?

It may seem strange to conclude this chapter by asking whether the lab is a place for STS because for most of the field's short history, it has been considered to be *the* place for STS, the archetypical location for STS fieldwork. And it is still the case that spending time in the laboratory gives one credibility as an STS scholar. But this is a room that unambiguously belongs to the scientists, and everyone else is a visitor there.

This is not to deny that being in the lab provides excellent opportunities to learn about the scientific research, and I appreciated being able to observe the difficulties of engineering living things in practice, seeing firsthand the workarounds and dead ends that do not find their way into scientific papers. I was struck by the recalcitrant nature of the objects in the lab, particularly the "yeastiness" of the yeast and the humility it required of the researchers. It continually overflowed and exceeded the constraints of engineering and its aspirations for standardization and control. This was not merely something of interest to note, however. An argument I will return to in future chapters is that being attentive to the difficulties of imposing engineering onto biology can be the beginnings of a more normative position. Since biology does not comply with the instrumental agenda of engineering, engineers working with biology have to become open to the possibility and potential of the living world. They are challenged to think differently and to consider alternatives to dominant instrumental rationalities.

I valued my time in the lab, but I think the place of such studies in the future of STS is uncertain. Being invited by scientists to spend time in their laboratory has always been a rare occurrence and is likely to become even more so in a funding climate where social scientists are increasingly expected to deliver ELSI research for apparently contentious fields such as synthetic biology. A lab study that is not tied to the exigencies and discomforts of collaboration or intervention seems to have become something of a luxury. In the future, it may become more common for STS researchers to do what I did in the synthetic yeast project and introduce the idea of going into the lab after the research has already been funded. As my experiences have shown, the reasons we are invited to be part of large scientific research grants may not align completely with our own, but negotiation is often possible.

In the synthetic yeast project, we had the advantage of an underspecified description of our work in the proposal, which meant we could investigate the issues that emerged from the laboratory work. Although the topics we chose to study—construction and comprehension, wholes and parts, chassis and yeastiness—were not topics that the senior scientists on the project proposal had expected us investigate, our interests were welcomed. However, even though we presented our work at several synthetic yeast conferences and published papers on it, many of the researchers on the project more broadly (although not those with whom we had spent time in the lab) adopted the default assumption that what we were actually doing was ELSI research, because this fitted with their conceptualization of the role of the social sciences in relation to the natural sciences and engineering.

This default assumption is understandable because it positions us as being part of their endeavors, helping solve problems in bioethics, biosecurity, regulation, or public engagement that might be an impediment to the advancement of their research. The value of this type of work is more obvious than the value of an observational study that treats the scientists as "lab rats,"[3] and does not involve a commitment to the success of the project as a whole. Although I attempted to observe the scientists in a way that was not objectifying, one interpretation of the scientists' positive reaction to my miniprep is that it allowed them to position me as *more* than an external observer of their actions.

I would have liked to have been more collaborative in the laboratory, but I found this much easier in other spaces, such as the coffee room and the art studio. I did gain new conversational partners in the lab, and there are people with whom I have a connection even as they have moved on to other groups and projects. But my relationships with the PhDs and postdocs in the lab are not my most significant in synthetic biology because I was not working *with* them, as I did with the scientists and engineers in some of the other rooms. As an observer, I was not part of a shared endeavor.

This points to some of the limitations of observation. Like the feminist scholars cited at the start of this chapter, I am troubled by the idea that observation is the ideal methodological position for an STS researcher. As I will describe in chapter 4, I have found it methodologically, ethically, and personally preferable to adopt more collaborative relationships with the synthetic biologists I engage with. If observation is the primary methodology of laboratory studies, then it is necessary to go beyond laboratory studies and, in doing so, reflect on what is sometimes taken for granted as an appropriate methodology for STS.

Some maintain that it is possible to do a kind of laboratory studies that is not primarily observational, and this is something I will address in chapter 5 on the art studio, but as my account demonstrates, I found it difficult to do more than observe. This was due both to the nature of the laboratory space and the people within it. As noted above, the laboratory is a secluded, bounded, protected space, which is specifically designed to keep the outside world out. Of all the rooms I describe in this book, it feels like it has the thickest walls. Within these walls the scientific agenda dominates because the room is specifically designed to further this agenda. One enters as a visitor and a guest to learn what is happening there and simultaneously enters into relations of obligation to one's hosts. These obligations become heightened when the people in the lab, on whose time and goodwill one depends, are relatively junior and in temporary posts. Finding myself in this situation, it felt inappropriate for me to make critical interventions or to try to suggest that things should be done differently.

Perhaps this is because I had become domesticated by this space, in a similar manner to the way in which the laboratory domesticates and tames the objects it studies. When I told one of the other synthetic biologists at Edinburgh that I had done a miniprep in the synthetic yeast lab, he immediately asked if I had taught the scientists any of my social science techniques in return. This had not even occurred to me because I had intentionally put myself in the position of a learner. But his comment did make me concerned that I had indeed become domesticated. I had attempted to mitigate this from the start by choosing not to spend all my working time in the synthetic yeast lab, retaining a base in the STS department. Entering the lab one or two days a week is perhaps best described as being "adjacent." This is a recommended positioning put forward by Paul Rabinow and Gaymon Bennett (2012, 177), anthropologists who have been closely involved in synthetic biology, because it allows one to move "both into and out of an experimental situation." Despite my attempts to practice adjacency, I do think the environment of the lab, and my relationships with its members, had an influence on my critical capabilities.

There are reasons to move beyond the lab. It houses a relatively narrow range of people with similar interests and agendas. It assumes and reinforces an observational methodological orientation on the part of STS. It does not allow for direct investigation of significant features of scientific developments, such as intellectual property regimes or community-building initiatives. Other places, such as international conferences, bioethics committees, and policy rooms, seem to be more relevant locations for the making of a scientific field. And moving to spaces such as these allows for critique by throwing other contexts into relief. This is not to deny that the lab is important. It has a materiality and temporal stability that other, more ephemeral sites lack, and it provides excellent opportunities to learn about the science and the practice of observation. In fact, in the context of a dominant ELSI research agenda, we may have to make special efforts to get access to this space. I feel the pull of the lab but also want to go beyond it, which is why for the rest of the book I explore other rooms that open up new opportunities for intervention and collaboration as well as observation. I turn next to a room that allows for greater intervention than the laboratory: the conference room.

2 THE CONFERENCE ROOM

It was in an elegant high-rise apartment in the verdant grounds of the National University of Singapore that I unpacked my suitcase for the Synthetic Biology 7.0 meeting in June 2017. By that time I had become familiar with synthetic biology conferences and their regular attendees. In fact, the conference room was one of the first places I seriously engaged with synthetic biology. It was a room where I was exposed to many different flavors of the field and spent a great deal of my time. It was a place for observation, but the price I often had to pay for entry was to give a talk, which provided me with opportunities for intervention and decisions to make about what to do with these opportunities. This reflected the idea—even the desire—that "the social" be represented in synthetic biology meetings, which set them apart from conferences in many other scientific fields. I explore these apparently distinctive features of synthetic biology conferences below, but I start with some reflections on carrying out research at conferences.

CONFERENCES AS A RESEARCH SITE

Although conferences have been the focus of social scientific research in fields such as education studies (e.g., Skelton 1997), they have been somewhat neglected by science and technology studies (González-Santos and Dimond 2015). An exception is Hess (2001, 240), who identifies conferences as important fieldsites for second-generation STS ethnography, which, as noted in chapter 1, is marked by the move away from traditional locations such as the laboratory toward more multi-sited research. More recently, there has also been emerging interest among STS researchers in conferences as places for knowledge production, sociability, ritual, and performance (Cool, Cakici, and Seaver 2017; Supper and Somsen 2018).

Most of the social scientific literature on conferences sees them primarily as sites for observation. This is not surprising because conferences often take place in rooms such as auditoriums that are designed for this purpose. The audience is expected to spend the majority of their time in silence, watching what is being presented. In contrast to the lab, where an observer is to some extent an intruder on the day-to-day activities of those being observed, in the conference room the speakers know their work will be on display. Acknowledging this dominant focus on observation in the conference room, my aim in this chapter is to also consider it as a site for intervention.

Charles Taylor gives the name "topical common spaces" to those spaces where people gather for a particular purpose, "be it ritual, conversation, the enjoyment of a play, or the celebration of a major event" (Taylor 2002, 113). In these spaces, people attend to a "common object or purpose together, as opposed to each person just happening, on his or her own, to be concerned with the same thing" (113). These physically and temporally simultaneous gatherings describe the conference room. Because they are distinctive kinds of experiences, it is perhaps not surprising that there is often a sense of comradery at conferences. People remove themselves from their familiar environments and travel—sometimes long distances—to meet up with others who are also not at home. Like airports, conferences temporarily bring together international, often jet-lagged participants, but at conferences, the attendees are there for a determinate and shared reason and for an intense, short space of time. There is something about this physical and temporal upheaval that can make the experience distinctive and memorable. Conferences also have their own rules of behavior and disposition. Friendliness and gregariousness are normal, and collegiality is expected. But the conference room is a more formal space than the coffee room or the pub. Conferences almost always involve an element of performance (González-Santos and Dimond 2015), and they often bring people together who have not met before.

Conference rooms are not public spaces, but they are not entirely closed, either. For the speakers, they are often spaces that one is invited into, although this is not the only way to gain entry to the conference room. The four major synthetic biology conferences I describe here allowed anyone to pay the registration fee to participate, and drawing on synthetic biology grants, I did this for two of the four. Having to buy access to this space obviously excludes those who cannot afford to attend, which often means those who are not part of academia or industry. And even once one has gained an "entry ticket" (Rip and Joly 2012, 3) to a conference, either through invitation or payment, there may well be additional checks to ensure that only legitimate attendees can enter. The boundaries of the conference are usually policed by the display of the conference badge.

A significant feature of the particular series of synthetic biology conferences I discuss here is that they were sites for the privileged. Their geographical locations alone—Hong Kong, Stanford, London, and Singapore—show the expectation of access to funds for long-distance travel and point to the privileged worlds the scientific elite (and those who associate with them) occupy. Privilege is not a feature of all conferences; nor is another feature of these particular synthetic biology conferences that was notable, which is that they were thrilling. They were thrilling for me partially because they took me to parts of the world I had never been to before, but also because there was the sense of something important, timely, and significant going on in these meetings. I use the word "thrill" because it has connotations of both danger and addiction.

Many of these conferences, and my experiences in synthetic biology more generally, also had elements of the playful, even the exuberant. But because they were spaces of privilege, this playfulness coexisted somewhat uneasily with the presence of financial and political power. This is a reminder that entering a conference room usually involves entering someone else's space, which requires and constrains certain behaviors. The question of the extent to which one can challenge the frames in the conference room is therefore a pressing one.

Conferences were one of the most important ways in which I learned about synthetic biology with the scientists and engineers I was sitting alongside. They were the events that made me decide it was worth investing my time and research efforts into this field. At these conferences I found a group that was open, interdisciplinary, and invested in community-building and exploring alternatives to the political economy of biotechnology. Small interdisciplinary workshops were also valuable sites for my interactions with the field, but I save consideration of these for later chapters.

Here I focus on four large synthetic biology conferences that were part of the Synthetic Biology X.0 conference series (SBX.0) and considered to be the flagship meetings of the field: SB4.0 in Hong Kong in 2008, SB5.0 in Stanford in 2011, SB6.0 in London in 2013, and SB7.0 in Singapore in 2017. These were rather unusual for scientific conferences in that there were opportunities for social scientists to contribute to all of them. I organized an interactive session at SB4.0, was on a panel at SB5.0, was on the organizing committee for SB6.0, and was an invited speaker at SB7.0. These four conferences sweep across nearly a decade of synthetic biology, which was new and emerging in 2008 and by 2017 had become more mainstream and conventional. Discussing them allows me to trace my changing role, from enthusiastic observer to disillusioned interventionist to domesticated critic. But before heading to these four internationally known locations, I start with the first conference I attended in synthetic biology, just outside the regional English town of Swindon.

FIRST ENCOUNTERS: SWINDON

The first national synthetic biology meeting that took place in the UK, simply called "Synthetic Biology Workshop," was held in February 2007 in a modern purpose-built conference hotel. It was organized by the UK's Biotechnology and Biological Sciences Research Council (the BBSRC). It was my first real exposure to synthetic biology and became particularly significant in retrospect.

To give some background: In 2006 there was evidence of increasing interest in synthetic biology in the US, marked by the National Science Foundation's funding of the Synthetic Biology Engineering Research Center (SynBERC), a large, multi-institutional center.[1] The International Genetically Engineered Machine (iGEM) competition, an undergraduate synthetic biology competition (discussed in chapter 3), was growing, with some international participation. But European involvement in synthetic biology was nascent. A report by the European New and Emerging Science and Technology (NEST) High-Level Expert Group on Synthetic Biology noted in 2005: "Much of the research so far has been pioneered by individual groups in the US, and the European research community has been relatively slow to embrace the field" (NEST 2005, 5). Wanting to encourage research in this area, the BBSRC organized a two-day meeting.

At the time, I was studying the social dimensions of systems (not synthetic) biology at the University of Exeter as part of a center for "Genomics and Society," which employed philosophers, social scientists, and historians.[2] The center was invited to send representatives to the synthetic biology meeting because the research councils had decided that social scientific engagement in potentially contentious technologies at an early stage was beneficial. This was partially due to the negative public reaction to genetically modified (GM) foods in Europe and also to the idea that the ethical, legal, and social implications (ELSI) of synthetic biology needed to be addressed, as discussed in chapter 1.

Arriving at the conference hotel, I was asked for my name on the list of attendees. Next to each name was a disciplinary affiliation, such as "computer scientist" or "engineer." I was surprised to see next to a few of the names, including mine, the phrase "member of society." Although this descriptor was not used consistently throughout the conference ("social scientist" was also used), it was present in the discussions and printed materials. This phrase raised questions for me about the assumptions that were being made about my identity and expertise—questions that became particularly pressing as the meeting progressed (and more pressing as the years progressed). Why should I, a social scientist, be labeled as a member of society when the scientists and engineers at the meeting were not? I put this question to one of the organizers, who said that she had hoped I would represent society's views. But since I did not do research on public engagement or public attitudes, I was rather perplexed.

The first morning of the meeting consisted of talks from scientists and engineers and a bioethicist. On the afternoon of the first day, we were set an overnight "design challenge" with the 66 participants split into small groups "each including one member of society" (as the conference program put it) and tasked to "design novel biological functionality in an organism of choice." My group was made up of a chemist, a biochemist, a bacterial geneticist, and a physicist. This forced interdisciplinarity exercise could have been uncomfortable, but instead it was playful, unexpected, exuberant—qualities that were present in many of my subsequent engagements in the field. The combination of humor, seriousness, and excitement was beguiling.

Based on the expertise of the bacterial geneticist and the chemist's passion for amateur percussion, we decided to design a singing bacteria. Caught up by the idea, the biochemist fetched a CD from her car to provide accompanying music. We brainstormed into the evening and over dinner. On the second day, the groups were instructed to assemble as before, only without the “members of society” who, according to the program, were expected to gather together to “give due consideration to ethics and wider impact.” But I refused to leave my group, which I now think was prescient. As I wrote in my field notes, I did not want to engage in predicting the potential negative implications of the technology, nor in clearing a path for its smooth uptake. I noted for the first time a disjunction that would later become familiar: The things that interested me about synthetic biology were not what the organizers assumed would interest me. Rather than representing society and taking an evaluative stance, my interest was in the generative nature of the interdisciplinary experimentation in my group.

I have recounted this meeting because it was the first significant synthetic biology event with that title in the UK and also because it marked the beginnings of my awareness of the expectations and assumptions about my expertise as a social scientist that I would increasingly confront. My handwritten field notes, which I did not reread until ten years later, are striking in that they show that some of the reflexive quandaries that later became familiar were new to me then. For example, I wrote frustratedly about how I had to continually explain myself and my expertise and interests.

The concluding comments from the representative of the BBSRC had significant implications for the development of synthetic biology in the UK. She asked the delegates how the funding agency should build a synthetic biology community in the country and noted that this was a challenging task because of the necessity for biologists and engineers to work together. A decision was made that it was premature to invest in research and that interdisciplinary networks should be funded as a first step.

THE SBX.0 MEETINGS

This decision had consequences that I return to in chapter 4, but I now fast-forward a year and a half to October 2008, to the first international synthetic biology meeting I attended, which was part of the SBX.0 conference series. The first of these meetings—SB1.0—was held in 2004 at the Massachusetts Institute of Technology, hosting 290 people. SB2.0 took place in 2006 in Berkeley with 327 attendees, and in 2007 SB3.0 was held in Zurich, with 351 people registered (Emergence Newsletter 2007). Thanks to my involvement in the Edinburgh-led synthetic biology network that resulted from the decisions made at the Swindon meeting, I had funding to attend SB4.0 in Hong

Kong in 2008. A conference series can be seen as a marker for the consolidation of a field or perhaps something that brings a field into being (Stephens and Dimond 2016). Because of the central place of the SBX.0 meetings in synthetic biology, and because of their significance for my understanding of and engagement with the field, I focus on them for the remainder of the chapter.

SB4.0 IN HONG KONG

I was rather excited to be going to Hong Kong—it was my first trip to Asia and the longest distance I had ever traveled. Once I arrived, the exhaustion and mild euphoria of jet lag combined with the warm and humid climate all contributed to the experience. I caught a ferry from Kowloon to Hong Kong Island and took a photo of the distinctive Hong Kong skyline. On arriving at the conference the next day, I saw that the front cover of the program had a specially commissioned painting of that same skyline, with the difference that all the buildings looked like they were grown from organic materials. There were attractive shell-like, sponge-like, and plant-like structures, with oversized lilies floating on the water of Kowloon Bay and simpler shapes, perhaps representing microorganisms, submerged underneath it. We were clearly expected to imagine that this was the type of world synthetic biology could bring into being.

The first page of the conference program depicted—this time in words—another ideal world of diverse groups coming together in this meeting space: "From undergraduates to Nobel laureates, from civil society and government leaders to investment bankers, and from high school teachers to legal scholars, the conferees of SB4.0 reflect the incredible diversity of interest, expertise and expectation to be found within the synthetic biology community." An avowed commitment to a diversity of attendees was a feature of all the SBX.0 conferences I attended, but it was particularly striking to me at my first one. It followed a precedent set in the earlier SBX.0 meetings, where the programs show that contributions were made from social scientists and humanities scholars as well as representatives of government and industry. For example, the anthropologist Paul Rabinow gave a plenary talk at SB1.0 in 2004.[3]

The SB4.0 meeting, held at Hong Kong University of Science and Technology, opened with an introduction by Drew Endy from Stanford University. Endy was a key figure in setting up synthetic biology in its early 2000s incarnation (see Campos 2013; Roosth 2017) and was the founder of the BioBricks Foundation running the conference. In his talk, Endy maintained that synthetic biology was not just for science, technology, and profit but also for "fun, love, diversity, equity, humanity."[4] He linked this idea to what I came to see was central to all SBX.0 meetings—the importance of building a community. As in the conference program, in his comments Endy explicitly extended this community beyond scientists and engineers to include "colleagues from social sciences, civil society organizations and industry."[5] This made the conference different from any scientific meeting I had previously attended—it was not assumed that I was merely there to observe; as a social scientist, I had been named as being part of this community.

This diversity extended to the conference sessions. In the run-up to the meeting, anyone could propose session ideas, and in the final program, approximately a fifth of the parallel sessions were on what could broadly be called "social" issues, including biosecurity, intellectual property, and commercialization. The remainder of the sessions were unsurprisingly more conventional and technical. All were punctuated by tea breaks with dim sum, during which attendees filed outdoors to warm up from the intense air-conditioning.

Of the nontechnical sessions, one titled "Global Social Impact" was particularly notable because it was organized by one of the most active civil society groups in synthetic biology—the Canadian-based ETC Group.[6] It was supported by the BioBricks Foundation and the Alfred P. Sloan Foundation, which paid the speakers' airfares so that they could attend.[7] The involvement of the ETC Group in the field can be traced to a letter written by 38 civil society organizations to the attendees of the 2006 SB2.0 meeting in Berkeley, in response to a call for self-regulation by the synthetic biologists. The letter expressed concerns that "this potentially powerful technology is being developed without proper societal debate concerning socio-economic, security, health, environmental and human rights implications" (ETC Group 2006). At their SB4.0 session, this letter was framed by the opening speaker (Pat Mooney from the ETC Group) as a productive way to start conversations. The next ETC Group speaker, Jim Thomas, focused on the potential for "landgrabs" on plant matter in the Global South by synthetic biology companies, raising issue of power, control, and social justice. Thomas said that although the synthetic biology community saw itself as young, open, and ethical, it was becoming clear that corporate interests had already taken hold of the field—and a glance at three of the opening pages of the conference program, covered in company logos, would seem to bolster this view.

This parallel session was well attended, with about 50 people present. At the end, one audience member asked those who were actively engaged in synthetic biology to raise their hands. To everyone's surprise, only two did so. This reflected, to some extent, the diversity of the conference attendees. A significant minority of the approximately 500 participants were not scientists and engineers, as the conference program had anticipated. Rather than attending the Global Social Impact session, the vast majority of synthetic biologists had chosen to attend one of the other three parallel sessions, all of which were technical in focus. There may have been a diverse community present at the conference, but it had stratified itself. The pleas in this session for a more equitable synthetic biology went largely unheard by those who were actually creating the technologies.

In this session, as in the technical sessions, I was in the role of the observer. This was not a straightforwardly passive activity because it involved avidly taking notes and discussing the talks with other participants in the breaks. I concluded that attending this conference was an excellent way to learn not only about scientific and technological developments but also about the ways in which "the social" was understood, incorporated, or excluded. However, as with all the conferences I discuss in this chapter, I was not solely in an observational role.

At this conference, my more active involvement was thanks to the fact that anyone could propose sessions. Feeling the weight of the substantial investment in our travel costs by the UK research councils, and also thinking that we might have a good opportunity for some data collection, two of my social science colleagues and I proposed an interactive session called "Genome Engineering Futures and the Role of the Synthetic Biologist." We used the session to run a "causes" and "consequences" exercise to explore the role synthetic biologists have in shaping social as well as technical futures (for further details, see Frow and Calvert 2013b). The session was poorly attended, largely because it clashed with a "special lecture" by Nobel Prize winner Sidney Brenner. But those who attended engaged actively, and although our intervention was not wide-reaching, it meant that we did more than just take notes from the safety of the auditorium.

SB5.0 IN STANFORD

The next meeting, SB5.0, took place in Stanford, California, in June 2011. When registering for this conference, I was surprised to come across a photo from SB4.0 of myself and a social science colleague featured prominently on the registration web page, a visual portrayal of the fact that we were considered to be representatives of the synthetic biology community.

As with SB4.0, the cover page of the conference program was striking, but not for its artwork this time. A strongly normative statement was given prominence. It was the mission statement of the BioBricks Foundation, which again was the organizer of the meeting. It read: “Our mission is to ensure that the engineering of biology is conducted in an open and ethical manner to benefit all people and the planet. We envision synthetic biology as a force for good in the world” (BioBricks Foundation 2011, 1).

Unlike SB4.0, where there were many parallel sessions, SB5.0 was all held in plenary. After an outdoor breakfast of bagels and Californian orange juice, 700 delegates took their seats in a large, swelteringly hot Stanford University auditorium. As in SB4.0, a considerable subgroup of the attendees were social scientists, ethicists, policymakers, government and industry representatives, with a few artists and designers in the mix. By 2011, I was familiar with a large proportion of this subgroup, as well as the majority of the UK scientists and engineers at the conference and some of those attending from other countries. I was reasonably at home in this community.

I also had a role in the program, but not thanks to my own efforts. After registering for the conference, I kept an eye on the online program as it developed. Three months before the meeting, most of the invited speakers and sessions were detailed, apart from one session with the title “Interacting with Society,” which had no further information. Less than a week before the conference, I received an email asking if I would be on this panel which, I was told, would address how the synthetic biology community might engage with the broader context of their work and pursue policy and public understanding opportunities. I was given a list of the other invited panelists, which included another STS researcher, a lawyer, a public policy researcher, an artist, an employee of the United Nations, a journalist, and someone from industry. I agreed to contribute, seeing it as an opportunity to feed back some reflections to members of the field I had by then been engaging with intensively for several years, although there was clearly little time to plan my contribution.

The session itself was an hour and a half long. It started with two presentations and some discussion between the presenters and the chair.[8] The ten panelists then had only a few minutes each to make their contributions, which was far from ideal. All of this was done under the heading of "Interacting with Society," which was problematic since it implied that synthetic biology was not part of society but that society was something that needed to be interacted with. Despite these inadequacies, it could be argued that the fact that there *was* such a panel in a plenary session in a high-profile international scientific conference is itself notable.

In contrast to SB4.0, there were no representatives of civil society organizations present at the Stanford meeting, which pleased some delegates. One blogged that he was glad that there were "no stunts from 'civil society' groups looking for their next fear bullet point for fundraising" (Carlson 2011). But after the conference, three of these organizations (the ETC Group, Friends of the Earth US, and the Center for Food Safety) sent a joint email to the BioBricks Foundation and copied all the "Interacting with Society" panelists to express their concerns about not being on the program, noting that while industry, government, and the military were well represented at SB5.0, civil society voices were marginalized. Perhaps the ready availability of social scientists (like me) "on tap" had allowed this to happen.

SB6.0 IN LONDON

SB6.0 took place at Imperial College London in July 2013 in the wealthy borough of Kensington. Partially in response to the hastily organized Interacting with Society session at SB5.0, I was asked to be on this conference's executive program team (EPT), along with my Edinburgh STS colleague Emma Frow. Although all the previous SBX.0 conferences had integrated social, ethical, policy, or regulatory discussions to some extent, this was now an opportunity to shape the whole program. I wrote in my early field notes (partially to quell my reservations): "This is exactly the kind of thing I should be doing. This is exactly the way to increase interdisciplinary interactions and broaden the range of voices. This is a natural next step."

Regular video calls with the international team organizing the meeting started over a year before the conference. The rest of the EPT was made up of young, thoughtful, and energetic synthetic biologists. My STS colleague and I worked with the encouragement and support of the EPT to integrate perspectives from the social sciences, policy, and bioethics into almost all the sessions on the program. We even secured a well-known STS researcher—Wiebe Bijker—as a plenary speaker. But despite our early-stage involvement and the supportive team, the end of this conference marks the nadir of my experiences in synthetic biology.

The first day was perhaps the most successful from an STS perspective. We organized a session called "Design and Synthetic Biology: Connecting People and Technologies." Bijker gave a talk on how all technologies are value-laden, using examples from his well-known work on the social construction of the bicycle (Bijker 1997). To my great satisfaction, one of the local synthetic biologists tweeted after this session: "Proud to be cycling home on my bicycle and now appreciating its politics." Christina Agapakis, a synthetic biologist and designer, spoke about the connections between science, technology, and society and introduced philosopher Isabelle Stengers's notion of slow science (Stengers 2011), challenging the community to step back, slow down, and think through their assumptions. It was exciting to see these perspectives getting a plenary airing.

Over the following two days, very different messages were delivered to the audience, however. Speakers warned attendees that synthetic biologists would face the "blind revenge of opposition," that they should fight against undue regulation, and that if they were not careful they would be destroyed by activist nongovernmental organizations (NGOs).[9] They were told that what was needed was "more technology and less ideology."[10] All of these comments perpetuated technocentric ideas that Emma and I had intended to challenge. And the climax of the meeting showed the connections between synthetic biology and powerful political voices: the UK Minister for Universities and Science announced to a cheering crowd a £126 million investment in synthetic biology—a field that he claimed would "heal us, heat us, and feed us."

On the third day, we organized a parallel session on responsible research and innovation (RRI), with a panel of invited speakers from the social sciences and humanities. This session had an audience of approximately 50, which filled one of the smaller lecture halls, but there was a moment of déjà vu. As had happened during the Global Social Impact session at the SB4.0 meeting, one of the audience members asked how many synthetic biologists were in the room, and only four people raised their hands. Just as in Hong Kong, most of them had gone to the technical parallel sessions.

There were two nonprogrammed interventions that were significant. One was an open letter jointly written by two NGOs, Luddites200 and Biofuelwatch, multiple copies of which were distributed to conference attendees. To put this in context, we had not succeeded in securing any civil society speakers on the official program because by 2013, those NGOs that had previously participated had decided their efforts were better invested elsewhere. This clearly left a gap that was filled by these two groups. Their letter pointed to "the technocratic mindset" of the synthetic biologists and argued that this mindset led them to overlook social causes of environmental catastrophes in favor of technical solutions. One of their key objections was, "Your tool is a hammer, so every problem looks to you like a nail."[11] Having a letter from NGOs distributed at a conference like this caused a considerable stir.

The second intervention was a poster designed by two STS PhD students. Displayed alongside the scientific posters in the official poster hall, it was a defilement of an iconic synthetic biology comic book called "Adventures in synthetic biology," originally published in *Nature* (Wadey et al. 2005). The students used many of the same images from the comic book but changed the text to display what they saw as the hubris of the field and its lack of consideration of power and social inequalities. Alongside synthetic biology, one of their main targets was us—the social scientists who had collaborated so closely with the field.

In a blog post that accompanied their poster, the two students said that they wanted to show how STS criticism had been assimilated and institutionalized. They argued that "'participation', 'responsible innovation' and 'collaboration' . . . are now an additional step in the smooth path linking the laboratory to the marketplace," and that "social scientists have now built ties with synthetic biology that are too deep to be in position to call for radical changes"; instead, they are "part of a process for the assimilation of criticism" (Anonymous 2015). Along with other social scientists at the meeting, I was perturbed by this intervention. It challenged me to reflect on the role I had assumed in the field.

Rereading my notes on SB6.0 is a sobering reminder of the difficulties of trying to bring the sciences, the social sciences, and the humanities into the same room. My STS colleague and I had tried our best to diversify, broaden, and challenge, but the event had nonetheless been dominated by powerful political and scientific actors forcefully putting forward a certain vision of the future of synthetic biology. I concluded that this conference room was not our space.

Admittedly, the role I played in the conference undoubtedly contributed to my disappointment with the event. As an organizer, I was heavily invested in the meeting and perhaps had a heightened expectation of what could be achieved. It is also the case that active intervention (i.e., being on a program committee) is always likely to be less comfortable than observation. And it is significant that my notes are not consistently despondent. In them, I recognized that there was a tremendous feeling of positivity and excitement among the scientific attendees. As with all the SBX.0 meetings, there was great enthusiasm for a field that saw itself as young, unconventional, interdisciplinary, and open, and enjoyment in being part of a unique shared experience. It was also the case that my STS colleague and I, with the unwavering support of the rest of the EPT, had inserted considerable diversity into the program, far more than is normal for a scientific conference. Many attendees seemed to appreciate this diversity, and I later learned that it inspired the organizers of the SB7.0 conference to attempt something similarly ambitious.

SB7.0 IN SINGAPORE

I now come to the conference that took place in Singapore in 2017. As noted in the introductory chapter, I had planned that this conference would mark the end of my fieldwork in synthetic biology. The conference was in Asia, as it had been in 2008, neatly topping and tailing my empirical work.

This time the organizing committee was made up entirely of early-career synthetic biologists, with no social scientific involvement. I attended as an invited speaker for a plenary session called "Art, Critique, Design and Our World." On the first day, after a short, hot, and humid walk from my allocated apartment to the conference venue, I came across many familiar faces. By June 2017, my involvement in synthetic biology for nearly a decade meant that some of the conference participants were my friends. A historian and fellow-traveler in synthetic biology remarked that it felt like a family gathering.

It had been four years since the last SB6.0 meeting in London, a bigger gap than between any previous SBX.0 meetings. This was because, to quote the conference wiki page, "the SBX.0 conference is not a normal conference series. Actual meetings happen only if, when, and where they need to happen."[12] The theme of this conference was "Revolution 2/Revolution, Too." Representing this theme, the conference poster was made up of five concentric circles (see figure 2.1). The outer circle contained drawings of Singaporean skyscrapers, their vaguely organic form reminiscent of the SB4.0 program's depiction of the Hong Kong skyline. The next circle had minimalist blocks of different lengths, resembling the output of a molecular biological assay. The third circle showed simplified cells, viruses, and naked strands of DNA. The next circle depicted insects and charismatic megafauna that, we were told during the conference, represented notable Singaporean animals. The inner circle had the characters "SB7.0," with human hands of diverse hues reaching out from it, representing the ethnic diversity of Singapore, or so I surmised. In an animated version of the poster, all the circles rotated in different directions at different speeds. Dizzying revolution, in its literal sense, was depicted.

The conference's wiki page explains that "Revolution 2" refers to a second turning of the wheel. It says that some of the excitement that motivated the formation of synthetic biology in its early days had waned, and it was time for a reassessment. "Revolution, Too," the page goes on to say, refers to "change also." It notes a concern that "as synthetic biology has matured it has been organized and adopted in ways that reinforce the status quo." This sentence resonated strongly with me, since this is what I had been observing over the last decade. The field that I had initially been attracted to because of its openness, its interdisciplinarity, and its willingness to imagine different kinds of innovation appeared to be giving up on many of these radical stances. In a video call with the organizers leading up to the meeting, the speakers in my session were tasked with metaphorically ridding synthetic biology of rust and using our talks to disrupt people from their familiar tracks.

The conference had grown again, and in the introductory comments we were told that the attendees numbered around 900, from 39 different countries. Uncharacteristically for these meetings, the first keynote talk was given by the CEO of the meeting's "premier sponsor"—a company called Intrexon. This was a thinly veiled sales talk. Emotive language and images were used to depict the good that genetic engineering had done and could do in the future, if it were not for people's "squeamishness." I was not the only one who was troubled by the simplistic understanding of "the public" that was presented in this talk, and many of the synthetic biologists reacted negatively to what they saw as ungrounded scientific claims. After the talk, many participants

FIGURE 2.1
The SB7.0 conference poster. *Source*: Jennifer Cook-Chyros, Chyros Designs.

noticed that the lanyards attached to the conference name badges were Intrexon branded. In protest, some people removed them, replaced them, or turned the ribbon around so the company's name was not visible.

The "Art, Critique, Design and Our World" session included a collection of five talks from those of us who had been challenged to disrupt people from their familiar tracks.[13] A talk by the critical designer Daisy Ginsberg interrogated the notion of "better" in synthetic biology, specifically the assumptions that synthetic biology will produce better biology, better nature, and a better world. The bioartist Oron Catts delivered a critique of the engineering mindset that drives synthetic biology. He argued that any attempt to control living things is an act of violence—making direct reference back to the Intrexon talk—and he drew attention to synthetic biologists' tendency to favor techno-fixes over behavioral changes.

I started my talk by highlighting the features of the field that had drawn me to synthetic biology in the first place, such as its disciplinary and institutional inclusiveness. Then, drawing on my own observations as well as the discontent expressed by some of my synthetic biology colleagues, I argued that these features seemed to be disappearing. Synthetic biology was becoming more like business as usual and being subsumed into more established fields, such as industrial biotechnology, and its parameters of success were being narrowed to the easily commercializable. Turning to my own role, I expressed concerns that my own presence in the field had just facilitated, placated, and enabled what would have happened anyway. I suggested that I had become an example of the "domestication of critique," and that I was just taking up a place on the program that should have been filled by more radical and critical voices. My final slide was a quote from the science fiction novel *The Hitchhiker's Guide to the Galaxy*: "So long and thanks for all the fish." I used it to mean that I was leaving the field.

Although I felt that this was the most critical talk that I had given to a synthetic biology audience, somewhat to my surprise it seemed to be listened to and engaged with on its own terms. I had pertinent discussions with a wide range of participants on the whole spectrum of topics that I had covered in my talk. Not all the reactions were positive; some synthetic biologists asked me why I was annoyed with them, and a few thought I was not critical enough. One STS researcher said that his ethnography of synthetic biology included me as one of its examples of a social scientist who had become too close to the field. This criticism (which I must admit frustrated me at the time) is similar to that made by the two STS PhD students at SB6.0, and it raises, again, the difficult issue of proximity that I return to below.

The rest of the conference was extremely wide-ranging and had a feeling of being slightly unhinged. A local organizer told me that his experience of the SB7.0 meeting was aptly represented by the animated conference logo of multiple concentric circles, all going around in different directions at different speeds. For example, speakers were still being added to the closing session only hours before it started. This was partially because the BioBricks Foundation organizers wanted to make the conference an exemplar of diversity. And they succeeded in this sense: Unlike many other international scientific conferences, only 10 percent of the speakers were from the US, and the gender split was 50:50 (quite an achievement for a field where engineering figures prominently). Multiple nationalities and seniorities were represented on the stage. The SBX.0 meetings had established themselves as a distinctive space.

The audience was generally young and enthusiastic, but several of the more seasoned attendees told me that they saw this as more of a community-building event than a science meeting. They considered the US-based SEED (Synthetic Biology, Engineering, Evolution, and Design) conference, which had been running annually since 2014, as the place where the serious science was done. The format of the SEED conference is much more conventional, and there are rarely invited speakers from outside the natural sciences and engineering.[14]

A difference from the SB6.0 meeting in London was that industrial, scientific, and political elites were less dominant in Singapore. There were only a few people dressed in dark suits, and they looked rather out of place. While at SB6.0 only the speakers had been invited to attend the conference dinner, at SB7.0 the banquet was open to all attendees and was held inside a huge greenhouse on Singapore's Marina Bay. It exhibited Singapore's multinational character in both the food and the entertainment, which included Malaysian drummers and Indian and Chinese dancers. I left the meeting exhausted but much more enthusiastic than I had been after SB6.0. I even played with the idea that this was *my* space. I had many shared questions and interests with the other participants and felt that I was part of the community. Perhaps I should not have thought of it as my swan song.

SCIENCE AND TECHNOLOGY STUDIES IN THE SYNTHETIC BIOLOGY CONFERENCE ROOM

After this tour through different countries, climates, and emotions, what can be concluded about the conference room as a place for STS? I would say that it is a room that provides excellent opportunities for observation and learning about a scientific field. Observation in the conference room is more straightforward than in the laboratory because the speakers expect to be watched and can choose what to present, so it is less problematic to do detached data gathering in this space. But the synthetic biology conference room provides opportunities to go beyond observation. It is a site that also allows for intervention, and these interventions can potentially reach many scientists and engineers. If one chooses to intervene from within the conference room, there is always the danger of being domesticated by this space, however. In this final section, I address these issues, drawing on the five events discussed previously.

My experiences in the synthetic biology conference room show that it is a sometimes thrilling spatially and temporally constrained site for the privileged, where the playful and the powerful coexist and where there is a sense that something special is happening. As the SB7.0 wiki page put it, "The SBX.0 conference is not a normal conference series," and I would concur with this statement in the sense that these conferences were never just about building biological things; they were also about building a community. This was stated explicitly during the SBX.0 meetings to such an extent that it could be considered performative, since the talk of building a community actually brought that community into being. It was significant for me that as a social scientist, I was named as being part of the community at the first of these conferences I attended, because this made it hard for me to take the position of the critical bystander. Naming people as part of your community is perhaps a good strategy to encourage them to become part of it. But there were some social scientists at these conferences who chose not to embrace this opportunity, which shows that the conference room is a room one can enter to different degrees.

Another feature of all the SBX.0 meetings is that they had explicitly normative agendas. This was most notably seen in the (then) tagline of the BioBricks Foundation, prominent on the front page of the SB5.0 conference program, which expressed the bold aim to “benefit all people and the planet.”[15] This is not how a scientific conference is normally framed. The SBX.0 conferences were also distinctive in that there was a persistent idea that “the social” needed to be somehow represented. However, as demonstrated by the Interacting with Society session at SB5.0, this representation was often inadequate. And at SB6.0 in London, our attempt to incorporate diverse perspectives into the meeting was undermined to a significant extent by the dominance of the voices of elites.

Furthermore, as both the civil society panel at SB4.0 and the RRI panel at SB6.0 somewhat painfully demonstrated, when a session was designed to challenge the participants to think more broadly than their science, hardly any scientists and engineers chose to attend it—all the seats being taken by the large number of “others” who regularly attended the SBX.0 meetings. There was enthusiasm among the organizers to include these kinds of sessions, but the synthetic biologists voted against them with their feet. This perhaps shows the difficulty of trying to introduce challenging or unconventional sessions into technical meetings. Or maybe these sessions were merely “window dressing”—making the conferences look more diverse, open, and socially informed than they would have otherwise.

The very idea of representing “the social” has troubled me since my first synthetic biology conference in Swindon in 2007. The difficulty of separating the scientific from the social has already been challenged in chapter 1, on the laboratory, and will be returned to in chapter 6, on the bioethics building. But it was in Swindon that I first became aware that the aspects of synthetic biology that interested me as a social scientist were not those that others expected would interest me as a “member of society” involved in synthetic biology. This is a recurring theme; in my field notes on SB6.0 in 2013, I listed the topics I felt the participants had wanted to talk about, which included public attitudes to science, risk, and safety and what (if anything) went wrong with GM crops. Although I have learned more about these topics over the years, I would not say they are my areas of expertise. Social scientists specializing in these topics are perhaps better placed to make contributions to these conferences.

I was, of course, not a lone social scientist in the synthetic biology conference room. A distinctive and enjoyable feature of this room is that as an STS researcher, one is often one among many “others” also studying the field. These others were simultaneously involved in the proceedings and stepping back to reflect on them. We were all attempting to make this messy experience into something we could use, something that could at some point find its way into our writing. I would not have stayed with synthetic biology if there had not been a readily available community of reflexive commentators to engage with. Peer support in the conference room—a room where one can be in an insecure and liminal position—can be valuable and even emboldening. This was particularly significant for me at SB6.0 when my STS colleague Emma Frow was also on the organizing committee. I could not have imagined doing this job alone.

Although having peers from social science, policy, history, art, and design to turn to during the breaks was a significant part of my synthetic biology conference experience, it was equally important that I could turn to colleagues from science and engineering. These colleagues included junior researchers I had spent time with in the laboratory, synthetic biology faculty from my own university, and scientists and engineers from other institutions whom I had got to know over the years. Of course, the synthetic biologists I interacted with were those who were particularly interested in certain types of discussion and reflection. But these conversations were not just examples of the comradery and friendship that the intense experience of the conference room can engender; they were also a way of making sense of what was going on. For example, it was rewarding and also a relief to find that my frustration with the Intrexon talk at SB7.0 was shared by many of the synthetic biologists at the meeting.

These interactions with social scientists, scientists, engineers, and others draw attention to a distinctive feature of observation in the conference room, which is that everyone in this room is an observer of sorts. This can have unexpected consequences: As a speaker at SB7.0, I became the object of observation myself, as part of another social scientist's ethnography. Moreover, it is not only observation that can be conducted with fellow conference-goers; the break-time discussions allow the early stages of data analysis to be carried out somewhat communally.

Communal data analysis could be considered a form of collaboration, and the synthetic biology conference room is a place where the boundaries between observation, collaboration, and intervention can easily blur. Collaboration is most prominent in the social activities that take place beyond the official conference program, however, and I will focus on collaborations in these informal spaces in chapter 4 on the coffee room.

In the more formal environment of the conference room, I found myself repeatedly asking the question: Whose room was it? At my first international synthetic biology conference in Hong Kong, I felt it was definitely the synthetic biologists' room. At SB5.0 in Stanford, I was familiar with many of the participants, and I knew people better still by SB6.0 in London. But I concluded in London that this conference room was not my space because of my inability to counter the dominance of powerful voices, despite being on the organizing committee. Perhaps this shows that one can feel at home in someone else's room, but if one tries to make it one's own, this changes the stakes. In Singapore, unlike in London, I did not try to change the room. I was a guest in that space, but I felt surprisingly comfortable in the interdisciplinary, collegial, and somewhat unhinged environment I found there.

In becoming more comfortable in this room, I simultaneously made myself less comfortable in my own disciplinary environment. Perhaps stepping into one room necessarily means stepping out of another and feeling more of an alien in your own academic context when you eventually return to it.[16] For several years, I spent more time at synthetic biology meetings and conferences than at STS ones, and the colleagues that I have in synthetic biology are as long-standing as those I have in STS. It is perhaps not surprising that some observers from STS see me as having gone over to the "other side."

This brings me to the point that over the course of the SBX.0 meetings I attended, social scientists gradually took the place of representatives of NGOs and civil society. The Global Social Impact session that the ETC Group ran at SB4.0 in Hong Kong was perhaps the most overtly critical session of all the synthetic biology conferences I attended (and it was the only occasion when the civil society participants received synthetic biology–related funding to attend). As discussed above, civil society representatives did not participate in Stanford at SB5.0, and the ready availability of social scientists may have made it easier for these voices not to be included.

At SB6.0, we (the organizers) were unsuccessful in securing civil society participation, and perhaps as a result, both NGOs (represented by the open letter from the Luddites200) and "activist" social scientists (with their critical poster) made themselves heard, although they were not formally part of the program. In contrast, anti-Greenpeace comments were made explicitly in some of the plenary talks. One of the notes I made to myself after SB6.0 was that we should have made more efforts to get NGOs in the room, but in a manner where they would not be subject to attack. At SB7.0, there were no NGOs, civil society organizations, or related critical voices. Instead, social scientists, artists, and designers appeared to have been tasked to tick this box by being challenged to bring a critical perspective. This is when I concluded I was an example of the domestication of critique.

I trace the beginnings of my domestication back to my first synthetic biology meeting in Swindon, where rather than taking the opportunity to convene with the other "members of society," I chose to remain with my group of scientists and engineers. Some might conclude that it is not surprising that my attempts to intervene critically at subsequent meetings were unsatisfactory. The most significant opportunity I had was at SB6.0, when I was on the organizing committee, but it was at SB6.0 that I felt most disillusioned with the field and my role in it. At this conference, all participants could choose their own image for their conference badge, and I had chosen the cartoon character Wile E. Coyote, to represent the trickster role I had hoped to play at the event, disturbing engrained ways of thinking. But at the end of the meeting, I regarded this choice as an ironic fail.[17] I was not a trickster at all. Instead, I had become part of the synthetic biology establishment and helped to legitimize the field by my very presence.

One of my conclusions immediately following this conference was that it was perhaps better for STS researchers not to be involved in synthetic biology conferences at all. I reflected in my field notes that it was important that there were counterpoints or alternative views expressed in every session, but that these did not necessarily have to come from social scientists. I concluded that interactions with experts in ecology, regulation, and standardization might well be more valuable. At one point, I even played with the idea that just having a straightforward science conference was the best option because of the almost insurmountable challenges of trying to insert a critical voice into this space. As I asked myself, is it better that "the social" be included, but in a way that is perhaps unsatisfactory or inadequate, or is it better that it be excluded altogether, as it is in many other scientific conferences?

Despite my doubts, I did opt for a more involved, interventionist role in these synthetic biology conferences. And this led some to conclude that I had sold out. But it is perhaps too easy to see social scientific involvement in synthetic biology as a choice between being a "sellout" and a "detached critical scholar." Most positions fall between these two extremes. For example, the two PhD students who produced the critical poster at SB6.0 had paid the conference registration fee and were on the list of participants, showing their complicity with the field to some extent.

At the start of this chapter I raised the question of whether it is possible to challenge the frames from within the conference room. I have shown that to intervene from within this room, one has to surrender some critical distance, to get *too* close to a field, in a sense. Perhaps such an internally interventionist position is not a good one from which to attempt to challenge the dominant frames. Of course, the bigger question is whether it is possible to challenge the frames from *within* any space—whether Oron Catts's provocative presentation at SB7.0 succeeded in doing so, for example. Or whether it is necessary to be somewhat outside a space—like the Luddites200 were at SB6.0—to expose assumptions and show that things could be different. This is an issue I return to in the following chapters.

3 THE CLASSROOM

Classrooms, at first glance, are not especially interesting rooms. They are familiar places, particularly within universities, that give over large amounts of space to unremarkable seminar rooms and lecture halls. Classrooms dictate certain norms of behavior and are usually closed to those who are not officially registered to attend the class, but within them there is considerable flexibility. The whole gamut of academic subjects can be taught and discussed.

This chapter focuses on a particular form of science and technology studies teaching in the classroom that has been singularly important in the history of the field: "service" teaching for students studying science and engineering. Although STS researchers do teach students in the social sciences and humanities, and some have their own students in dedicated STS programs, the service mode of teaching is the dominant one, and it describes my experiences in synthetic biology.

I start this chapter by briefly discussing STS's historical connections to pedagogy and then turn to a teaching site that is distinctive to synthetic biology—the International Genetically Engineered Machine (iGEM) competition. iGEM is an unusual informal teaching venue that provides opportunities for social scientific contributions, and it has a prominent place within the field of synthetic biology. It culminates in a large annual "Jamboree". I describe my pedagogical experiences in iGEM and my increasing ambivalence about this space over time. I then turn to more formal teaching experiences with master's students in synthetic biology and ask what sensibilities STS researchers are attempting to introduce through their teaching. I argue that intervention, albeit of a slow and sustained form, is the most important mode of STS engagement in the classroom. I conclude that the classroom has to be a space for STS: we are dependent on it for the persistence of the field.

THE ORIGINS OF SCIENCE AND TECHNOLOGY STUDIES IN THE CLASSROOM

STS arguably owes its existence to the classroom. As outlined in the introductory chapter, in the late 1960s, in the context of broader pressures for cultural and political change, there were calls across Europe and North America "to raise students' awareness of the need for greater responsibility in the uses and applications of science" (Jasanoff 2016, 231) and for the training of scientists in universities to be broadened. As a result, STS was introduced into the curriculum for physicists, chemists, and biologists, and departments were set up to deliver this teaching (Rip 1999).

To give an example, the Science Studies Unit at the University of Edinburgh, which became the department where I am now based, was founded in 1966 by C. H. Waddington, a geneticist who had strong interests in the arts and philosophy. Along with other progressive scientists of the time, he believed that scientific work should reflect the needs of society (Benda 2012). He reportedly told David Edge, who was hired as director of the unit, "We'll teach 'em the science—you teach 'em the rest" (Henry 2008, 226). Despite this rather vague remit, David Bloor, one of the founding members of the unit, later confessed: "I'm not sure that Prof Waddington really got what he had hoped for" (Bloor 2003, 173). Rather than delivering teaching on "the rest"—what might now be called the ethical, legal, and social implications of science—and leaving the science unanalyzed, the Science Studies Unit made scientific practice itself the object of inquiry, developing groundbreaking research into the sociology of scientific knowledge (Ziewitz and Lynch 2018). At the end of this chapter, I return to the question of whether the synthetic biology teaching that my colleagues and I now deliver at Edinburgh is closer to what Professor Waddington had hoped for.

Across the world, much STS work has similar pedagogical origins, and the academic positions of many STS researchers today depend on the teaching they deliver to scientists and engineers. This access to the classroom turns it into a potential fieldsite, albeit one with distinctive features. Notably, the power dynamics are very different from those more typical in STS research because instead of "studying up" (Forsythe 1999)—that is, studying those who are in a more powerful position than the researcher—in a teaching situation, the STS researcher is the one judging and evaluating the student.

THE SYNTHETIC BIOLOGY CLASSROOM

STS researchers are not involved in the teaching of every natural science and engineering student, of course. As has been shown in the previous chapters, however, synthetic biology is an interdisciplinary field that places importance on "the social"—and this carries through to the classroom. A distinctive feature of the synthetic biology classroom, and one that provides an entry point for STS, is the iGEM[1] competition, which is my main focus in this chapter.

In iGEM, teams of students from around the world compete to build simple biological devices using synthetic biology. They work in their home universities over the summer months and come together to present their work at the annual Jamboree, usually held in Boston in the autumn. iGEM started in 2003 as a class internal to the Massachusetts Institute of Technology and broadened to a competition between a few US universities in 2004. In 2005, the first UK university (the University of Cambridge) joined the competition, and the University of Edinburgh entered a team in 2006. The competition grew rapidly. In 2019, 3,500 participants in 346 teams from 46 countries attended the Jamboree.[2]

The synthetic biology standards network I became part of in 2008 (described in chapter 1) brought together the five universities in the UK that had at that time participated in the iGEM competition. This meant that iGEM was (indirectly) responsible for my involvement in synthetic biology, as it was for many of the scientists and engineers I worked with over the years. The synthetic biologists at Edinburgh invited me and my STS colleague Emma Frow to advise the iGEM team in 2008, and I attended my first Jamboree in 2009, becoming a regular attendee and judge at the competition until 2016.

iGEM is an unusual form of pedagogy, and the Jamboree itself is a distinctive experience, so iGEM has received considerable attention in the press (e.g., Mooallem 2010) as well as from scientists interested in teaching (e.g., Farny 2018; Hallinan et al. 2019) and from social scientists who have been involved (e.g., Balmer and Bulpin 2013; Cockerton 2011). I will not replicate this literature here, but iGEM cannot be overlooked as a teaching space; it is not only central to the parts-based approach to synthetic biology but also to the norms and values of the field, its motivations, its future, and—most significantly for this book—its attempts to incorporate social scientific perspectives.

iGEM AND SYNTHETIC BIOLOGY

The involvement of undergraduates in synthetic biology is often highlighted to demonstrate the characteristic inclusiveness of the field. Other epistemic and social values associated with parts-based approaches to synthetic biology are also constitutive of iGEM (Farny 2018). In fact, the competition was initially set up to test and further the objective of making biology easier to engineer (Smolke 2009) by requiring that iGEM teams build and then deposit interchangeable biological parts in a specific format—BioBricks—into the online Registry of Standard Biological Parts (Frow 2013).[3] This requirement means that the number of BioBricks in the registry grows every year, and they are freely available for other teams (or anyone else for that matter) to use in future years, in line with rhetorics of openness and democratization that are features of this approach to synthetic biology.

Another characteristic of iGEM is its interdisciplinarity: Teams comprise students taking courses in the biological sciences, computer science, and engineering. The competition also requires that teams do some work in the area of "Human Practices," which covers a broad spectrum of social, ethical, philosophical, and regulatory topics. It is because of Human Practices that social scientists, ethicists, and legal scholars have become involved in iGEM, and Human Practices has provided an opportunity for these groups to influence a large number of prospective synthetic biologists at early stages of their careers, when they have not yet fully embraced the identity of "biologist" or "engineer" and are often open to other disciplinary perspectives.

For these reasons, iGEM provides a distinctive teaching opportunity for social scientists. But advising an iGEM team is not a conventional teaching experience. Teams do not follow a structured course; they come up with their own ideas, design their own projects, and organize their own time. Because the competition is student-led, the social scientist's role is that of an adviser rather than a teacher, and the hierarchies are less clear-cut as a result. At Edinburgh, the students are not even physically located in a classroom. Instead, they are allocated an underused common room with a few computer terminals, basic tea-making facilities, plants, and posters made by previous iGEM teams. They spend the summer between this space and a nearby laboratory, where they build and test their genetic constructs.

Despite working without much formal supervision, iGEM teams are almost always highly motivated, and although some engage with Human Practices more than others, it is usually rewarding to interact with them because most are just as happy to read and reflect on an STS article as one from a science journal. Another benefit of working with iGEM teams is that they have a specific project around which to orient their Human Practices work, which focuses discussion in a way that is often productive. However, iGEM is above all a synthetic biology competition, and the students are encouraged to position synthetic biology as a solution to the world's problems. The limitations of this framing are addressed below.

THE JAMBOREE

Although iGEM teams do the majority of their work in their home institutions, the Jamboree is the culmination of the competition, and it is a distinctive feature of iGEM as a teaching space. A jamboree is a "noisy revel; a carousal or spree," according to the *Oxford English Dictionary*, and along these lines, Randy Rettberg, founder of iGEM and the president of the iGEM Foundation, explains that "it's mostly a party," a place where participants are encouraged to share their "passion about synthetic biology."[4] Until 2013, the Jamboree was held at MIT.[5] Teams presented their work in the Stata Center, a landmark building designed by Frank Gehry in 2004 that has external walls at unexpected angles, defying the expected symmetries of architecture. A blackboard-lined corridor runs through the building, which the iGEM teams covered in a graffiti of colorful chalk images, promoting their projects. The finals and prize ceremony were held at the Kresge Auditorium, MIT's biggest hall, but this venue rapidly became too small for the competition. In 2014, the Jamboree moved to the Hynes Convention Center in central Boston, which houses a large anonymous aircraft-hangar-like hall that could accommodate the growing number of attendees. In all these guises, the Jamboree, like the conference room, is a "topical common space" (Taylor 2002), allowing for a temporally and physically shared experience.

This experience is one where energy, excitement, and emotion are on display (and encouraged) to a greater extent than in the more formal conference room discussed in chapter 2. My field notes from the first iGEM competition that I attended in 2009 describe the palpable tension, the techno music played between sessions, the stadium waves in the auditorium, and the rather wild Sunday night party. The iGEM experience also has its own materiality—teams have matching T-shirts, emblazoned with the logos of their sponsors. They all present a poster and often bring stickers, badges, flyers, and even 3D-printed objects to promote their project. Teams sometimes wear variants of national dress or costumes relevant to their project—which in one case involved a student dressing up as a tardigrade. But despite appearances, the Jamboree is not just a party; it is also a competition. Teams practice their obligatory 20-minute presentations late into the night and often deliver impressively slick pitches with high-quality graphics and animation.

The purpose of this competition is to further the agenda of parts-based synthetic biology. Rettberg explains in the opening ceremony every year that iGEM is not science; it is engineering, because "we use cells as technology to change the world."[6] At the closing ceremony, he then asks the gathered crowd: "Can simple biological systems be built from standardized interchangeable parts?" Their cheering answers the question in the affirmative. He ends with a rousing speech. Drawing on his background in computer science and his role in the development of the internet, he argues that synthetic biology will become just as groundbreaking as this technology. He proclaims, to loud applause, that the students at the Jamboree this year will be leaders of the field in five years and that they will own private jets and invite him for rides.[7]

This ecstatic rhetoric is needed to counter the disappointment many iGEM students feel at the end of the competition, having battled to get their engineered biological systems to "work" during the summer (Balmer, Bulpin, and Molyneux-Hodgson 2016; Frow and Calvert 2013a) and often failing to win the medals and prizes they hoped for at the Jamboree. It is not unusual to see tears at the final ceremony. Competing in iGEM and attending the Jamboree is itself a mark of success, however, not least because of the considerable funds that have to be raised from sponsors for a team to participate. Costs include supporting the students over the summer, providing them with laboratory space and materials, paying the iGEM registration fee (which was $5,000 per team in 2019), and flying them to Boston to compete. For these reasons, iGEM is a privileged space that is dominated by scientific teams from leading research universities, although there have been some interesting exceptions over the years.

ARTSCIENCE BANGALORE

One of these exceptions was the team ArtScience Bangalore, made up of ten undergraduate students from Srishti School of Art, Design and Technology. Their presentation in 2009 remains one of my most memorable iGEM experiences. It was the first time that art and design students had competed in the competition, and they described themselves as "outsiders."[8] They decided to engineer the bacteria *E. coli* to produce geosmin, an enzyme that produces the distinctive smell of the soil after the rain. They explained in their presentation that their motivations were poetic rather than scientific because the earthy aroma after the first monsoon rains is particularly evocative in Indian culture and is represented in several Bollywood movies. A black-and-white film still depicting a couple lovingly gazing at each other under an umbrella was one of the slides accompanying their talk.[9] As art and design students, they had decided to use synthetic biology to evoke emotion and memory, rather than for the utilitarian purposes that dominated the rest of the competition. As they finished their presentation, it became clear that a venue that was largely uncritically technophilic had allowed for a moment of transcendence.

At the closing ceremony, the ArtScience Bangalore team was awarded the prize for best presentation. One of the judges announced, "We'd go as far as to say that this presentation changed the way we think about synthetic biology."[10] The students were praised for their resourcefulness and tenacity, and it is true that they did describe themselves as using a do-it-yourself approach and even created some of their own lab equipment.[11] But it would be misleading to present them as a resource-poor team, forced to improvise with what they had at hand. They were based in a leading arts institution in India and collaborated with the National Centre for Biological Sciences, one of the country's premier research institutes.

Having since worked with artists and designers in synthetic biology, I now see that the work of these students exemplified a certain kind of artistic engagement with the field.[12] The ArtScience Bangalore team did not celebrate the technology, nor did they criticize it directly. Instead, their chosen use (or perhaps subversion) of synthetic biology allowed for ambivalence and reflection and did not dictate a single interpretation. The presence of this team in the official program demonstrated that the competition could lead to the creation of singularly thought-provoking work.

HUMAN PRACTICES IN iGEM

ArtScience Bangalore did not present their work under the heading of Human Practices; the team did not attempt to incorporate "the social" or public attitudes into their work. As noted above, however, it was Human Practices that allowed for STS entry into iGEM. The term was originally coined by Rabinow and Bennett (2012) to describe their collaborative anthropological work with synthetic biology. They chose it because they wanted to avoid some of the negative connotations of ethical, legal, and social implications (ELSI) research, discussed in previous chapters. Human Practices first entered iGEM when one of Rabinow's students joined the Berkeley team in 2007, and it was officially taken up by the competition as a special prize and requirement for a gold medal activity in 2008 (gold medals are awarded to around one-third of all the teams). In 2013, Human Practices became a silver medal requirement, and in 2019 it became mandatory for the award of a bronze medal.[13] However, the way Human Practices has been interpreted in iGEM over the years has almost no resemblance to Rabinow and Bennett's conception of it (see Balmer and Bulpin 2013). Before 2015, teams were given little guidance on the iGEM web pages on what Human Practices should involve, and it was not until a comprehensive Human Practices Hub website was developed in 2017 that teams were offered an account of the origins of the term.

The Human Practices Hub presents a brief history and a straightforward definition: "Human Practices is the study of how your work affects the world, and how the world affects your work."[14] The students are told that "before you pick up your first pipette you should think about Human Practices" and to "consider integrating ethicists, social scientists, designers, law students, business students, and other experts into your team."[15] The guidance stresses that "social, political, economic, and ethical aspects of synthetic biology should not be an afterthought. . . . Rather, they should be considered from project conception all the way through the innovation process."[16]

At all the iGEM Jamborees that I attended, the majority of the teams undertook some kind of Human Practices work, of variable quality. Most teams did not, and still do not, have dedicated Human Practices advisers. Such advice is often not seen as necessary, and even when it is, it can be difficult for the science faculty supervising iGEM teams to identify colleagues who have appropriate expertise and are also willing to meet up with undergraduate science students regularly over the summer. As a result, teams often do Human Practices work with little guidance. At the first iGEM competition I attended in 2009, when Human Practices was still finding a foothold in the competition, most teams either did rather methodologically problematic internet surveys in an attempt to gauge "attitudes" to their proposed genetically engineered machine, or public outreach, which often aimed to educate and excite schoolchildren about synthetic biology. But there were also more interesting and focused studies of do-it-yourself biology and national regulatory frameworks, and a thoughtful 57-page report on "SynthEthics," which was authored by an STS student associated with a Paris-based team.[17]

The type of Human Practices activity that has since become recognized as one of the most valuable within iGEM has been labeled "integrated Human Practices." This is where the team shows how their Human Practices work—often involving discussions with relevant users, experts, and stakeholders—has influenced the design of their biological device (Frow 2015). This emphasis has led to some sophisticated and impressive examples of stakeholder engagement over the years. However, because integrated Human Practices assumes the existence of the technology and its circulation in a world of users or consumers, it necessarily precludes questions about whether a synthetic biological approach to a problem or need is preferable to a non-synthetic biological (e.g., social or political) alternative. It also cannot encompass work that disrupts existing problem-framings because this work will necessarily be difficult to integrate. As a result, the increased emphasis on integrated Human Practices has also made it harder for more reflexive or ambivalent work to find a place in the competition.

Like all other aspects of the teams' work, Human Practices is judged during the Jamboree. Judges at iGEM are volunteers, all of whom are given a distinctive hooded fleece at the start of the competition with the word "Judge" written in large letters on the back. Most judges are also iGEM team advisers, although others come from government agencies or the biotech industry. In the early days of iGEM, an incentive to judge—and one of the reasons I did so for several years—was that the substantial attendance fee was waived. I joined a dedicated group of Human Practices judges, one of whom sat in on each team's presentation along with three or four other scientific judges. In my experience, Human Practices judges were always treated as equals and peers by the other judges, and our expertise was respected, which was particularly significant when the Human Practices component of a team's project became the most important factor in deciding which medal they should be awarded.

There is not necessarily a consensus on what constitutes good Human Practices, even among the dedicated judges, however. It is evaluated not only by STS researchers but also by policymakers, lawyers, and academics from diverse traditions who have different epistemic and pedagogical values. Some of these individuals come with expertise in biosafety or biosecurity (e.g., in 2011, two Human Practices judges were from the US Department of Defense) and rate work that addresses these concerns above that which is more imaginative or idiosyncratic. Others value innovative, but typically one-way outreach activities, particularly if they reach a large number of people.[18]

Choosing to be a judge at iGEM meant choosing to accept this situation. Taking on the official roles of instructor and judge also meant unambiguously becoming a member of the iGEM community and not only having a stake but also a voice in the competition's outcome. There were many upsides to being part of this community and willingly becoming enrolled in this exciting and unconventional pedagogical endeavor. The Jamboree had similarities to the young, open, interdisciplinary synthetic biology conference room described in chapter 2. And being physically identifiable as a judge, thanks to the judging hoodie, led to many genuinely interesting conversations with students who were keen to talk about their projects during the poster sessions and at the breaks. There were other benefits, too: The first few Jamborees that I attended attracted many of the leading figures in synthetic biology from around the world, and all the competitions were accompanied by satellite events involving companies, regulators, and designers. My attendance at iGEM taught me a great deal about the field and its aspirations and cemented my relationships with many of the UK synthetic biologists who also crossed the Atlantic to attend. At iGEM, I saw the beginnings of projects that would go on to develop into academic papers, research grants, start-ups, and even research centers.[19]

Like the conference room, iGEM also contained a subcommunity of social scientists with interests in synthetic biology—some of whom were Human Practices judges while others worked alongside the teams as supervisors or even team members. This subcommunity provided an opportunity for comradery, reflection, shared analysis, and some minor dissent. As the presence of ArtScience Bangalore shows, a small number of artists and critical designers also occupied the space, provoking a particular form of critical reflection, which added to the richness of the experience.

BECOMING AMBIVALENT ABOUT THIS SPACE

There were always aspects of the Jamboree that I found uncomfortable. Every competition has an "iGEM from above" picture, where all the participants are photographed in a large group, showing the size of the competition in a starkly visual way (see figure 3.1). Teams in their matching T-shirts cluster together and are only distinguishable as blobs of color in the large crowd. Even at my first iGEM in 2009, the group was so large that I would not have been individually identifiable in the photo, but I purposely avoided it, not wanting to be visually captured as part of the techno-celebratory event, even in an anonymous manner. During the 2010 competition, I could not so easily avoid the requirement that all judges stand on the stage during the extended prize-giving ceremony with our official role in the competition clearly made public. Although I had opted to be part of this community, I was more comfortable remaining on the periphery of it.

As noted previously, in 2014, the competition moved to the Hynes Convention Center because it was one of the few venues in central Boston that could hold the large number of participants. The increased size of the competition and the soulless venue—particularly when compared to the quirky MIT Stata Center—made the Jamboree a less interesting space. The sheer number of people meant the event was more anonymous, and many of the leading synthetic biologists no longer attended. The judging switched from being discussion-based to ticking boxes on an online form, limiting the opportunities for cross-disciplinary learning and exploration (although respectful discussion still had a place on the small judging panels allocated to each presentation).

Several features of the 2014 competition made me feel more distanced from the event. That year the list of sponsors whose logos decorated the program included the controversial agricultural biotechnology giant Monsanto, and at times I felt I was part of a huge lobbying convention to promote genetically modified organisms. This feeling was accentuated when one of

FIGURE 3.1
iGEM from above (2009). *Source*: Photograph by David Appleyard and iGEM.

the organizers introduced me to his colleague by explaining that the point of Human Practices was to spread synthetic biology out into the world. In the closing ceremony that year, the idea of "community" was evoked by Rettberg, who maintained that "everybody here is part of this community." Rather than drawing me in, as performative statements of this type had in the first synthetic biology conferences I attended, I found this assertion off-putting and almost felt as if I was observing a strange cult.

This sense of alienation was significant because by choosing to play an official role in the competition, I had opted *not* to put myself in this distanced position of an observer. But the fact that I felt more comfortable on the periphery of iGEM than at its heart reinforces the point, made in chapter 2, that there is not a straightforward dichotomy between insider and outsider—instead, there is a spectrum of possible positions. As in the conference room, social scientists can decide how closely involved in iGEM they want to be, and some regarded those of us who chose to take on the judging role and its attendant paraphernalia with mild suspicion. It also has to be acknowledged that being an active participant—actually doing the job of judging the competition—was an all-consuming exercise, which meant that my ethnographic field notes from the Jamborees where I was a judge are scanty and inadequate.

The 2016 iGEM was the last that I attended. Having chosen to play an active role in the Jamboree for several years, I stepped away. This was because the agenda motivating the competition had become more explicit every year as it grew. As noted above, the objective of iGEM is to "use cells as technology to change the world," within a frame that only recognizes problems that lend themselves to synthetic biological solutions. Human Practices is then enrolled as a way of delivering those technological solutions to potential users. It became increasingly difficult to unsettle this dominant agenda. The critical designer Daisy Ginsberg (2018, 66) encountered similar obstacles when "trying to craft an alternative dream of better in the shadow of iGEM's imaginary." There seemed to be limits to what could be done in this space.

This is not to deny that there were pockets of opportunity and small openings that allowed for mutually enriching conversations and exchanges with judges, advisers, and students. And in every competition, there were some examples of reflexive, imaginative, and unexpected work from iGEM teams. But the scope for expressing ambivalences and exploring alternatives was limited, which raised questions for me about whether it was worth the investment of time, money, and effort required to participate in the competition.

I was not the only one who asked myself this question. Some of the synthetic biologists who were regular attendees talked nostalgically about the early years of iGEM when it was more intimate and the judging less formalized. They complained that flashy presentations and entrepreneurial ambitions were now rewarded more often than carefully designed biological circuits and open-access contributions to the Registry of Standard Biological Parts. Also, for synthetic biologists and social scientists alike, advising an iGEM team is optional. It is rarely "counted" in official university teaching loads because it takes place over the summer and relies on people's time, goodwill, and laboratory resources. Younger synthetic biology faculty often enthusiastically welcome iGEM teams into their labs for a few summers, but then they find that the "babysitting"[20] required can be a distraction from the more focused work needed to produce the publications and grants required to secure their future careers. Some opt out of the competition, and others pass the teams on to junior colleagues. iGEM advising is even more optional for social scientists, since most teams do perfectly well without it, and social scientific departments are unlikely to see the voluntary advising of undergraduate science and engineering students over the summer as a worthwhile pursuit. Things are very different, of course, when teaching is an income stream, as is the case with the majority of academic teaching and with the course to which I now turn.

SOCIAL DIMENSIONS OF SYSTEMS AND SYNTHETIC BIOLOGY

It was largely thanks to iGEM and the value it placed on Human Practices that Emma Frow and I were invited to contribute to a master's program on "Systems and Synthetic Biology" that was being developed by our synthetic biology colleagues at Edinburgh in 2010. We were initially asked to teach an "ethics" module, but instead we put forward a more STS-inflected ten-week course that we named "Social Dimensions of Systems and Synthetic Biology" (hereafter Social Dimensions). It was enthusiastically adopted by the master's program as a compulsory course, which now runs every year. Many other programs in synthetic biology similarly integrate some variant of Human Practices into their teaching, albeit usually to a lesser degree. In the UK, these programs often rely on guest lecturing from the geographically distributed smattering of social scientists interested in the topic. In fact, in a paper discussing their synthetic biology master's course at the University of Newcastle, Jennifer Hallinan and colleagues (2019, 29) note how it is often the case that social scientists, ethicists, legal scholars, and philosophers "with interest in synthetic biology and its implications are simply not available, and acquiring such experts is an on-going challenge for those running synthetic biology courses."

Emma and I designed our course to address topics we had discussed with iGEM teams and those we were pursuing in our own research. We ran sessions on different approaches to synthetic biology, interdisciplinarity, standards, ownership and sharing, access and security, publics, governance, futures and expectations, and design and aesthetics. I will not discuss the course content here because my aim is not to outline a primer for synthetic biology teaching but rather to explore the synthetic biology classroom as a place for STS. In this light, the topics we chose to teach are less important than the kinds of attitudes, sensibilities, and insights we attempted to introduce.

To make this classroom a place for STS, we first had to get to it. At the University of Edinburgh, like many other universities, the science and engineering students are located at a different campus from those in the social sciences and humanities. The King's Buildings campus, with its streets and buildings named after famous scientists, is only two miles away from the university buildings in the city center, but this constitutes a significant separation, even if one is a cyclist and can make it there in 15 minutes with energetic pedaling. Once we arrived at this location, our next task was to secure a room to teach in. This was not straightforward, given the different room booking systems in the different parts of the university (just one example of the practical obstacles placed in the way of cross-disciplinary teaching). The rooms we were initially allocated were set out with chairs in rows, all facing the lecturer at the front. Emma and I learned to arrive early to pull the chairs into a haphazard circle in an attempt to elicit discussion and materially assert the value of interaction and conversation. The size of the class grew steadily over time, and in 2013, we moved to a modern, airy seminar room in the Waddington Building, occupying a space named after the scientist who had started the chain of events resulting in our positions at the university. This building housed Edinburgh's Centre for Systems and Synthetic Biology, which had by then become a familiar location to us.

SCIENCE AND TECHNOLOGY STUDIES IN THE CLASSROOM

So what kinds of attitudes and sensibilities did we attempt to introduce through our teaching? We did not explicitly address this broad question when we started the course, and in trying to answer it, I find it helpful to turn to the work of other STS researchers on pedagogy. This work stresses the importance of providing a space for reflection in the classroom by allowing alternatives to dominant frameworks to be expressed. For example, in her teaching, Jennifer Croissant (1999, 23) aspires to show "that there exist other ways of looking at technosocial life," and Donna Riley (2019, 16) aims to teach "epistemic flexibility," which she describes as "an openness not only to other views but also to other avenues for arriving at other views," while Haraway (2014) describes education as attuning the capability to hear knowledges that are not one's own. Such awareness of epistemic diversity can "help disrupt and reimagine dominant images and practices of science and engineering" (York 2018, 79). The importance of disrupting and reimagining dominant images of science and engineering—of showing that things could be otherwise—is something that I return to in later chapters.

To initiate such disruption in the classroom, Maria Hesjedal and colleagues (2020, 1638) suggest the strategy of introducing "moments of dislocation" into teaching activities, which can unhinge "early-career researchers' mental maps about science and society." They say these moments of dislocation occur when students "become aware of discrepancies between their established practices and other practices, views, or organizational policies" (1638) or when they are forced to confront their differences of opinion with fellow students. Others note that bringing different disciplinary perspectives to bear on an issue can also be a valuable way of disturbing existing worldviews because of "the multiplicity and heterogeneity of ways of seeing that different disciplines offer" (Szerszynski and Galarraga 2013, 2817). In fact, interdisciplinarity has been described as a way of "perturbing the existing order of the world" (Callard and Fitzgerald 2015, 44)—a phrase that for me captures the emancipatory potential of teaching.

In the Social Dimensions course, there have been moments that have aligned with these aspirations. Sometimes the literature we have set as readings has performed the dislocating or perturbing function. For example, some students have found texts from the 1970s anticipating synthetic biology and its promises (e.g., Chedd 1971) strikingly prescient, challenging their conception of the novelty of the field. Others have resonated with work on colonialism (e.g., Roy 2018), and this has pushed them to rethink the relationship between politics and science. On other occasions, it has been the group conversations, the interactions within the classroom, that have been the most significant in shifting the grounds of the discussion.

But we have consistently encountered some ideas that are very resistant to disruption, most notably the "deficit model," which is prevalent among the students. The deficit model assumes that if nonscientists do not welcome scientific and technological developments, it is because they do not understand them, and if they learned more about the science, they would become more favorably inclined toward them (Gregory and Miller 1998). Such an understanding of science communication is one-way, and presupposes the dominance of a particular (scientific) way of knowing that does not help in attuning the capacity to hear knowledges that are not one's own. Other STS researchers talk about encountering similar views in their teaching. For example, in an interview, Gary Downey explains, "I wrestled with the question of how best to persuade engineers that there are other people out there who have different forms of knowledge and expertise than you, which are no less valuable than your own" (Downey and Zhang 2015, 16).

In my experience, the deficit model is particularly entrenched. This is perhaps not surprising since it is repeatedly reinforced by many within the broader science and engineering community (Wynne 2007).[21] Since the majority of the Social Dimensions students have been trained in the natural sciences as undergraduates, the course is a minor component of their overall educational experience, and other courses are likely to be regarded as more epistemically authoritative.

Yet it is the case that the students taking the course are exposed to work in STS once a week for a whole semester, and they do gain a gradual and growing familiarity with the material, resulting in subtle changes in the nature of class discussion and the quality of weekly written submissions. This has often only become apparent to me when I have done one-off guest teaching in other courses and at other universities, which has thrown into relief the shared understandings and connections that have developed with and between my own students over the semester.

Assessing the longer-term effects of teaching is not straightforward (see Bernstein et al. 2017). Like many other STS researchers, I have had a few students who have decided they want to reorient their careers toward policy, philosophy, or social science and others who have committed to integrating social, political, or economic concerns into their future scientific work. I have been thrilled when some have used course discussion as a platform to suggest new, radically interdisciplinary master's programs that combine synthetic biology, critical design, and STS. But since all students come with prior interests and experiences, it is difficult to attribute these choices and suggestions directly to the Social Dimensions course itself.

A small proportion of the students who take the course stay on at Edinburgh to do PhDs and postdocs in synthetic biology. I have a connection with those individuals, as any former lecturer would, and they have an awareness of the social scientific questions and topics relevant to their work. Whether they will carry this with them throughout their careers, and whether this means that the synthetic biologists of the future will be notably reflexive and open to diverse disciplinary perspectives, remains to be seen.

OBSERVATION, COLLABORATION, AND INTERVENTION IN TEACHING

I see the attempt to introduce STS perspectives and sensibilities to the classroom as a slow and sustained form of intervention. Before elaborating on this, I will briefly address the extent to which the classroom lends itself to observation and collaboration.

The iGEM Jamboree can be a site of observation for the STS researcher if it is treated as just another fieldsite, which it is by some. Although I did learn a great deal about synthetic biology from iGEM, it was difficult for me to adopt the position of a detached observer because I played an active, official role in the competition as an adviser and judge (although the competition did gradually push me closer toward an observational position). In the case of longer-term pedagogical interactions, substantive knowledge about future synthetic biologists and their views and orientations can obviously be gained from teaching, as is demonstrated by my observations on the prevalence of the deficit model among the students I taught. In this manner, the classroom does serve as a fieldsite where observations can be made. But it feels wrong to talk of observation as being the operative mode in the classroom, since teaching is active and involved.

Such active involvement necessarily includes an element of collaboration with one's students. Ingold (2013, 13), an anthropologist, emphasizes collaboration in his discussion of pedagogy, arguing that "the role of the student is not to take on board a corpus of authorised, propositional knowledge arising from a superior source in the academy, but to collaborate in the shared pursuit of human understanding." I aspire to this type of collaboration in my teaching, but I would not go as far as Andrew Balmer and colleagues (2016), STS researchers who say that their interactions with an iGEM team became one of their "most successful and fruitful efforts in collaboration" in the field of synthetic biology (143). As I will show in subsequent chapters, the coffee room and art studio were spaces where I felt I had more successful collaborations, although my collaborations with the scientists who were teaching the same students were undoubtedly strengthened in the synthetic biology classroom. We found ourselves together on course planning meetings and exam boards, with common interests in teaching methods, forms of assessment, and the progress of the students. This everyday collegial relationship was a reminder of how much I shared with my synthetic biology colleagues simply as fellow academics.

In my experience, it was intervention that was the dominant orientation in the classroom. In contrast to the temporally bounded and often high-profile interventions that can be made in the conference room, I would argue that the kind of intervention that happens in the classroom should be described as incremental or “soft” (Fisher and Rip 2013). Interventions in the classroom usually involve interacting with the same group of students repeatedly over time (whether advising a local iGEM team over the summer or teaching a course for a semester), so “attrition” or “erosion” seem to be the most appropriate metaphors here. Although class discussion, course assessment, and completed iGEM projects do give some indication of how successful these gradual interventions are, it is very hard to ascertain the long-term consequences of teaching. It may be that the classroom is the most important site for “critical, transformative interventions within technoscientific worlds” (Suchman 2014) because the students one engages with will go on to shape the future of synthetic biology, but this is difficult to assess.

THE CLASSROOM AS A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

This chapter has covered two different kinds of spaces. The iGEM competition is particular to synthetic biology, and its annual Jamboree is an unusual pedagogical environment. The Social Dimensions class is more broadly representative of STS teaching of science and engineering students.[22] There are similarities between these spaces, of course. For example, being able to teach in them is dependent on being invited to do so, which in turn relies on good relations with scientists and engineers.

The presence of Human Practices in iGEM legitimizes the involvement of social scientists in the competition as advisers and judges, and many of the students who participate in iGEM, who come from all around the world, assimilate the idea that Human Practices is part of the field. Advising an iGEM team can be a stimulating and rewarding experience, but it necessarily involves contributing to a large international event that has the guiding objective of furthering synthetic biology and the technological solutions it offers. This constrains what is possible within this space, which is why I stepped away from it. I would not rule out contributing to iGEM in the future, however, because it provides distinctive opportunities for student teams to develop original and thoughtful work, and at the time of writing, there are signs that the competition may change and develop into something that is not tied so strongly to a specific technological agenda.[23]

The Social Dimensions course occupies a more typical classroom space that the STS researcher can make their own by choosing what to teach, how to teach it, and what sensibilities to attempt to engender. In this classroom, the STS researcher is in a relatively powerful position, more powerful than in many of the other rooms described in this book. This may diminish when the students leave the room, however, because they are likely to return to contexts where received assumptions are reinforced. As my experiences and the accounts of others have shown, there is no guarantee that one will succeed in attempts to challenge dominant frames and explore alternatives in the classroom, nor are there straightforward ways to gauge the consequences of these pedagogical interventions.

This raises questions about *where* we teach and whether changing the location—compelling the students to take the course in the social science and humanities part of the university, for example—would alter the dynamics. Michael Bernstein and colleagues (2017, 877), writing about teaching on a residential summer school, argue that "separating participants from atmospheres of traditional science and engineering education and culture is critical to building a cohort in which students can critically reflect on the local and broader culture." But arguments can also be made for infiltrating teaching spaces owned by the natural sciences and making STS ideas more familiar within them.

In practice, it is usually necessary to teach science and engineering students at the location most convenient for them. This is the consequence of a situation in which the income that comes from teaching scientists and engineers is often essential for the academic livelihoods of STS researchers. Because STS is not an established discipline, it is rare for us to have our own students and degree programs, particularly at the undergraduate level. This institutional precarity means that STS is often dependent on established science and engineering disciplines for teaching opportunities, and these opportunities are not necessarily continuous or guaranteed. Rip (2018, 196), reflecting on a career in STS, notes the cyclical nature of his teaching contributions: "You do some interesting teaching and then after some time it's found less interesting and your space is reduced." Unlike some of the other rooms discussed in this book, for most STS researchers, the classroom is not a room one can choose to stay away from.

Yet one can choose what to do in the space that is available. And this brings me back to the question raised at the start of this chapter about whether the synthetic biology teaching my colleagues and I now deliver at Edinburgh is close to what Waddington hoped for when he set up the Science Studies Unit in the 1960s. Although I hope that it is not, I am suspicious that it is. As I have outlined, STS has its origins in the call to inject responsibility into science and technology. Without this call, STS would probably not exist. But a danger is that responsibility becomes conceived of as something that is extra and in addition to the science itself ("We'll teach 'em the science—you teach 'em the rest"), which takes the focus away from science and technology as objects of social scientific inquiry. The early members of the Science Studies Unit deflected these demands and used their teaching and lectures to develop the sociology of scientific knowledge. By doing so, whether intentionally or not, they managed to resist social science being positioned as an agent of the industrialization of science (Latimer 2019). Resisting this positioning is an ongoing challenge for STS researchers who teach scientists and engineers.

4 THE COFFEE ROOM

Tea, rather than coffee, is my hot beverage of choice. Nevertheless, informal social spaces like coffee rooms and bars have been significant locations in my interactions with synthetic biology. It is perhaps inevitable that after engaging with a group of scientists and engineers over several years, one ends up spending time with them in places like chain cafés in airports, restaurants in foreign cities, and local pubs. As Balmer and colleagues (2016, 74) have noted, "everyday practices like getting coffee can be crucial to opening science up more informally." It is these informal interactions that I explore in this chapter.

When I first started spending time in these spaces, they posed particular methodological challenges because the peer-type relationships and friendships that arose did not lend themselves to straightforward distinctions between social scientific researcher and scientific "informant." Instead, I found myself implicated and involved. This raises issues about the obligations and challenges of being an entangled social scientist in a scientific field, especially when there are often disparities in power and access to funds. Finding it impossible to adopt a detached observational stance in this space, I turned to anthropological literature that has argued for a shift from the language of "informant" to that of "epistemic partner" (Holmes and Marcus 2008). Building on this work, I advocate collaboration, particularly experimental collaboration, as a way of thinking *with* others. But I start by exploring the characteristics of the coffee room and, relatedly, the pub.

THE COFFEE ROOM AND THE PUB

I am folding together the coffee room and the pub because they have much in common. They are both places for refreshment, informality, and socialization.[1] They both have the distinctive quality of being public spaces where it is nevertheless possible to have intimate conversations with those around you (Shapin 2020). They are more informal than any of the other rooms discussed in the book, although many of the other rooms do have connections to such informal spaces. Conferences and workshops provide opportunities for nonprogrammed socialization, and lunch and coffee breaks are a regular feature of laboratory life. But I focus on the coffee room and the pub in this chapter because they raise important questions about methodology and collaboration. I consider these rooms mainly in the UK context, which is where the majority of my informal interactions with synthetic biologists have taken place. This obviously has consequences. The British pub in particular—often wood-paneled with local ales on tap—is a location with specific cultural resonances.

Both coffee rooms and pubs can be considered neutral territory. Social scientists do not enter these rooms as guests of synthetic biologists or other groups. The host is the venue itself, so the room in a sense belongs to nobody. Not being in the position of either a guest or a host can be liberating. Another feature that contributes to this sense of freedom is that the boundaries of these rooms are not protected or policed, in contrast to many of the other rooms where social scientists engage with scientists and engineers. It is possible to enter and leave when one pleases.

Although no official invitation is necessary to enter the coffee room or the pub, an invitation may well be required to join a particular social gathering at either location. At minimum, it is necessary to know when and where such a gathering is happening, which requires some insider knowledge. The coffee room and the pub are places where social scientific researchers are more likely to spend time after they have already built up some kind of relationship with the people they are studying. Neither is likely to be one of the first rooms entered as part of an investigation into a scientific field.

Livingstone (2003) notes that "every social space has a range of possible, permissible, and intelligible utterances and actions," and what is interesting about both the coffee room and the pub is that the range of permissible utterances and actions is extended. It almost goes without saying that the pub is a place where tongues are loosened, where people are emboldened to say things that they would not say in other contexts. And "having a coffee" can be a way to take a conversation away from a formal place of work and also from the ears of colleagues, perhaps providing a place for gossip or criticism.

HISTORICAL RESONANCES

I chose to focus on coffee rooms and pubs because of their importance in my investigation of synthetic biology, not because of their place in the history of science. Nonetheless, some aspects of this history are relevant, so I touch on them briefly here.

Coffeehouses in England in the 1700s became important places for the discussion of new ideas, often hosting scientific lectures and experiments (Livingstone 2003).[2] They were a key site in making what Jürgen Habermas (1989) called the "public sphere," "a place for social interaction outside the private sphere (the home) and the sphere of public authority (the state/court)" (Calhoun 2012, 75).[3] Coffeehouses playing this distinctive social role declined in the late eighteenth and nineteenth centuries (Berry 2005), so it should not be assumed that their features are shared with the coffee rooms of today. There are, however, three characteristics of the public sphere they embodied that help illuminate the coffee rooms discussed in this chapter. The first is disregard of status; the second is sharing a domain of common concern or interest; and the third is inclusivity, meaning that everyone is able to participate.[4] Equality and inclusivity were notable features of my experiences in both the coffee room and the pub. Having a topic of common concern—synthetic biology—was also fundamental to these sites.

In respect to both locations, it is significant that although I am talking about a space that is public, in the sense that it is open to the public (a pub is literally a *public* house), I am not talking about a space that exists for the public discussion of science and technology.[5] Instead, the coffee rooms and pubs that I spent time in were for informal socialization between people who were already acquainted.

ENTERING THE COFFEE ROOM

As noted in previous chapters, the way in which I became acquainted with synthetic biologists across the UK was by being part of one of the synthetic biology networks that were funded in 2008 for three years. These networks did not have money for research, but they provided opportunities for the participants from different disciplines and universities across the country to get to know each other in low-pressure contexts, with no demands to produce specific outputs. In fact, it was not until 2012 that the scientists at the University of Edinburgh became involved in a large multi-institutional synthetic biology project, and not until 2014 that they received funding for a dedicated synthetic biology center. This meant that there was an extended period of time for relationships to be built and topics of shared interest to be identified away from the demands of deliverables. Felicity Callard and Des Fitzgerald (2015, 35) point to the benefits of such open-ended interdisciplinary collaboration where there is no identified research problem to address and note how "this runs counter to many formal encomia for interdisciplinarity, in which different disciplines are often imagined as coming together to answer particular (already identified and identifiable) problems."

This contrasts with other social scientists' engagements with synthetic biology, significantly Rabinow and Bennett's work with the US-based Synthetic Biology Engineering Research Center (SynBERC) from 2006 to 2010. These anthropologists were confronted with unequal power relations, attempts to control their research agenda, and divergent expectations from scientists and funders (Rabinow and Bennett 2012). Although there are clearly similarities between their experiences and those of the social scientists who have interacted with synthetic biologists in the UK, one of the key differences is that our initial involvements were in low-pressure networks, whereas Rabinow and Bennett's first collaborations were in a multimillion-dollar, high-profile research center, so they were subjected to a great deal of pressure from the start. Our Edinburgh-based network, in contrast, allowed us to take part in everyday academic activities, such as going to conferences and teaching together, for several years before receiving external research funding.

The events I attended with my network colleagues provided ample opportunities for socialization. Official conference dinners have their own formality, but as noted above, more informal gatherings often happen around meetings and workshops—when searching for food together in unfamiliar locations, spilling out into the pub after a programmed event, or catching a coffee before one. This is not to overlook the fact that these venues can be exclusionary, not only because one must already be in the loop to be part of them, but also because in the UK context, socialization often favors those who enjoy a drink, whose English is fluent, and who are free of caring commitments.

IN THE COFFEE ROOM

So, what is actually discussed in the coffee room or pub? This is a place for what is often called gossip—about the key personalities in the field, their views and activities, as well as the micropolitics of different labs and institutions. But to imply that discussion is limited to topics of this kind would be misleading. Being in the coffee room or pub often involves being part of a community that cares about the same things. These spaces allow those in them to explore topics of common concern and to share a sense of excitement about them. For example, the pub often lent itself to heated discussions about what synthetic biology was and was not, who was really doing it, and who was simply adopting the label to further their own research agenda. These discussions were heated because it felt that something was at stake. As a social scientist, I did not passively observe these conversations. Instead, I was enrolled in them, asked for my views, and challenged to take a stand (which I did).

In fact, some of the most interesting discussions I have had about synthetic biology—on topics like the limits to standardization and control of biological systems and the role of the organism in an engineering-inspired field—have been in these social spaces. These were not "informal interviews" where I was eliciting information from others; they were shared intellectual explorations. Perhaps because of the willingness of synthetic biologists to cross disciplines, there was interest in what I could contribute based on my knowledge of both synthetic biology and social science (e.g., a follow-up email after one discussion asked me for a reference to the Collingridge dilemma).[6] These rooms also provided an opportunity to develop shared understandings of what constituted valuable work, both in synthetic biology (which, we concurred, was not simply metabolic engineering) and in social science (where problematic science communication was identified and analyzed). On some occasions, boundaries between disciplines blurred dizzyingly, with social scientists drawing on scientific findings and synthetic biologists referring to Bruno Latour and Donna Haraway in discussion.[7] In these circumstances, we shared epistemic enjoyment in collaborating, exploring ideas together, harnessing each other's reflective capacities, and building new understandings. These experiences are what I value most in my engagements with synthetic biology.

It is not a coincidence that these experiences occurred when drinking and eating with others. The Latin *cum panis*, translated as "with whom one eats bread," is the origin of the English word *companion* (and more obviously the Spanish word *compañero*); it points to the way in which eating with others is a way of connecting with them.[8] To put it more strongly, who we choose to eat, drink, and socialize with influences who we become. I chose to do these things with synthetic biologists, while some other social scientists did not, and synthetic biologists became my friends as a result. These friendships, like all friendships, transformed and shaped me. Since friendships are important for conceptions of the self (Tillmann-Healy 2003), the coffee room, like the conference room, can have implications for identity.

Friendships also present particular methodological challenges. They undo the distinction between social scientific researcher and scientific "informant." And traditional social science approaches, such as the interview, become less straightforward in friendships when ongoing conversations are the norm (Owten and Allen-Collinson 2014). Friendships take energy and effort to maintain; they require trust, and they involve obligations, concerns, loyalties, hopes, and fears. In short, they involve affect. Affect is, of course, familiar in ethnographic research (see Fortun 2005), although it is sometimes "treated as illegitimate, un-scholarly, 'soft'" rather than "integral to the process of understanding" (Kondo 1986, 85). Affect is also something that has received little attention in science and technology studies until recently (see Kerr and Garforth 2016; Latimer and Lopez 2019). However, I concur with Callard and Fitzgerald (2015, 128) who argue that "the affective weight of an interdisciplinary collaboration may be as much a datum to be considered as a situation to be managed." And the way I make sense of my friendships in synthetic biology is by understanding them as collaborations. Since collaboration is one of the three primary ways of engaging with synthetic biology that I am analyzing in this book, I take the opportunity to explore it in a little more depth here. I maintain that an emphasis on collaboration is consistent with STS work that has shown the always social and coproduced nature of scientific knowledge, but I take it further in applying this collaborative approach to STS itself.

COLLABORATION AND EPISTEMIC PARTNERSHIP

There has been a recent expansion in the anthropological literature on collaboration, to such an extent that commentators talk about "the collaborative turn in anthropology" (Strohm 2012, 100). This idea emerged as a response to "decolonization and the critiques anthropologists leveled at their own traditional disciplinary practices in the 1980s and early 1990s" (Riles 2015, 167). Collaboration was seen as a way of challenging the academic authority and privilege of the anthropologist and empowering the marginalized communities being studied (Sanchez-Criado and Estalella 2017; Lozano 2018). The situation is different for STS researchers, however, because we usually spend most of our time "studying up"—that is, studying privileged groups (Gusterson 1997, 114).[9] As Diana Forsythe (1999, 8) notes, when studying up, "the collapsed roles of participant, observer, critic, employee and colleague collide with one another." In fact, in my work on synthetic biology, these roles collapse to such an extent that I find it useful to think in terms of Sherry Ortner's (2010) notion of "studying sideways," because I am studying people who are very much like me—fellow academics in universities. When studying up and sideways, collaboration is not normally motivated by the desire to empower marginalized communities.

I found collaborating with synthetic biologists in the coffee room more rewarding than the observation I conducted in the laboratory or my often-unsuccessful attempts to intervene from within the conference room. Collaboration grows out of long-term relationships (Hess 2001) with those who come to be thought of as "epistemic partners" (Marcus 2008). Collaboration can even be thought of as a research method, a form of knowledge coproduction (Fortun 2005). It fundamentally involves acting and thinking with others. Such an approach was adopted by social scientists Callard and Fitzgerald (2015, 2) in their work with neuroscientists. They decided that they "might be able to make more interesting interventions by somehow collaborating *with* people in those sciences, rather than simply scrutinizing them, from the outside, as objects of historical, cultural, or sociological attention" (emphasis in original).

By collaborating, one necessarily becomes involved in "mutually interested concerns and projects" (Marcus 2008, 7) with the people one engages with. In these circumstances, it becomes not only practically but also methodologically and ethically problematic to merely observe scientists and engineers in order to extract knowledge from them. The anthropologist Michael Carrithers makes a similar point. He argues that thinking *with* others is something that emerges from the close relationships that develop in fieldwork, and that there is "an *ad hoc* morality of mutual recognition, mutual trust, and mutual forbearance which arises more or less spontaneously in the course of interaction" (Carrithers 2005, 438), particularly if this is a sustained interaction. This resonates strongly with my own experiences—the synthetic biologists I spent extended time with were not my informants; they were my collaborators, my colleagues, and my epistemic partners. I could not just study and observe them; I became part of their endeavors.

EXPERIMENTAL COLLABORATIONS

In my experience, the most generative form of collaboration is experimental collaboration. Experimental collaboration is a methodological positioning that has grown out of work in both anthropology and STS in recent years. Adolfo Estalella and Tomás Sanchez-Criado (2015, 303) define it as "a research approach that is collaborative in its relational form and experimental in its orientation to the production of knowledge." They developed this notion because they were unhappy with the traditional emphasis on participant observation in anthropology and the supposed distance it required, which did not represent what they experienced in their fieldwork. Instead, as I did, they found themselves engaged in "joint epistemic explorations with those formerly described as informants, now reconfigured as epistemic partners" (Sanchez-Criado and Estalella 2017, 10). In embracing this methodological approach they note "the secure place of expertise is traded for an experimental practice that asks us to try things out to risk collaborative encounters of uncertain outcomes" (304).

That outcomes are uncertain is central to the idea of experimentation. In fact, one definition of experiment is "a course of action tentatively adopted without being sure of the outcome" (Oxford Dictionaries 2016), and the word itself comes from the Latin *experiri*, "to try." The point that uncertainty is inherent to experimentation is also central to historian of science Hans Jörg Rheinberger's discussion of the topic. As he memorably puts it: "Experimentation, as a machine for making the future, has to engender unexpected events" (Rheinberger 1997, 33). Adopting experimental collaboration as a methodology means one has to be open to the unexpected. This is key to thinking *with* others, which requires engaging with different ways of seeing the world. Of course, experiment can also mean “a scientific procedure undertaken to demonstrate a known fact” (Oxford Dictionaries 2016), but it is the more open-ended notion of experimentation that is at play in discussions of experimental collaboration.

Other STS researchers also draw connections between collaboration and experimentation. For example, Teun Zuiderent-Jerak (2015) advocates “experimental interventions” and Michiel van Oudheusden and Brice Laurent (2013) talk about “experimental normativity”—both of which are empirically grounded in interactions with others in the research process. Callard and Fitzgerald (2015, 9) develop the idea of “experimental entanglements” and maintain that “different ways of being ‘experimental’ can open up new avenues through which to think and work collaboratively across distinct arenas of expertise.” A related notion is “collective experimentation,” which involves people coming together from diverse perspectives to discuss scientific and technological developments (Joly, Rip, and Callon 2010). Collective experimentation takes us beyond the scope of this chapter, however, because it extends these discussions further than interdisciplinary groups of academics to include stakeholders and publics (Stilgoe 2015).

It is experimental collaborations I want to highlight here, because I think the relations and understandings developed in the familiar spaces of the coffee room and the pub provide the foundations for these kinds of interaction, which can then be built on in other locations. Experimental collaborations are not motivated by instrumental aims, driven by top-down agendas, or tied to predefined deliverables. Instead, they are adventurous and playful and allow exploration of the unknown (Balmer et al. 2015). They are necessarily risky, and their outcomes are uncertain. They require certain dispositions on the part of all those involved, such as a willingness to challenge one’s own assumptions and to respect unfamiliar epistemologies and methodologies.

COLLABORATION, CONTAMINATION, AND COMPLICITY

This suggests that the importance of rooms for socialization and refreshment should not be underestimated, despite their everydayness. Although other spaces may be more elite, exclusive, and exciting, the coffee room draws attention to the importance of personal relationships, gradually built up over time. In their work on interdisciplinary collaboration, Callard and Fitzgerald (2015, 30) make a similar observation that “it is often the gradual accumulation and assemblage of minor interventions that make up the nitty-gritty of interdisciplinarity, over and above the big grant calls, major co-authored papers, and so on." In the best cases, I have found that the mutual understanding and trust that arises from repeated small-scale interactions can lead to an openness to the formulation of alternatives, something explored further in chapter 5, on the art studio.

Repeated interactions with specific groups do lead to what could be called "contamination," however. Anna Tsing (2015, 28) usefully defines contamination as "transformation through encounter." And Zuiderent-Jerak (2015, 187) similarly talks about how mutual "contamination" between sociologists and health care professionals can "modify the sociologists' identity and their normative concerns." I noted above the transformational nature of my friendships with synthetic biologists in the coffee room. The downside of socializing primarily with one particular group in this way is that the diversity of views that one is exposed to is inevitably limited.

Talk of contamination slips easily into talk of complicity, a term Marcus makes use of in his discussion of collaboration. He shows how "complicity" can be defined both as a "state of being complex or involved" but also, and more problematically, as "being an accomplice; partnership in an evil action" (Marcus 1997, 85). This reminds us of the negative associations of the word *collaboration*, "To co-operate traitorously with the enemy" (OED), which takes us far from the ideal of experimental collaborations involving epistemic partnership. Ortner also points to the always-present danger of complicity in "studying sideways," which can lead one to become "overly cautious in the interview situation, and timid in what one writes, wanting to please and impress informants" (Ortner 2010, 226). And parallels with the empowerment of research participants in the "collaborative turn" in anthropology become increasingly stretched when STS researchers are collaborating with those who have considerably greater access to financial resources. When we think *with* scientists and engineers, we are often thinking with the powerful. Although discomfort is a feature of many of the rooms discussed in this book, perhaps the coffee room is a space one can become too comfortable in.

THE COFFEE ROOM AS A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

This may seem to lead to the conclusion that the coffee room is not a good place for STS because of the limits it places on critique and intervention.

Spending time in this room almost compels one to collaborate, to become involved in the concerns and projects of those one is interacting with. However, I am loath to draw the conclusion that STS researchers should not pursue the friendships and mutual understandings that can be found in the coffee room because they do bring distinctive insights and rewards. Embracing the comfortable discomfort of this room seems to be necessary.

Another reason for spending time in the coffee room is that it is the least constraining space I discuss in this book, so there is considerable flexibility in terms of what can take place within it. This is partially because the room belongs to no one, so it is not necessary to leave one's own space and enter another's as a guest, as is the case in the laboratory or the conference room. And although scientists and engineers wield more power and resources than social scientists overall, the power relations in this room are not straightforward because the environment lends itself to an unstructured mingling of seniorities and interests.

One should keep in mind the transient nature of the social gatherings in this space, however. And the friendships on which these social gatherings are built can also be ephemeral; they can (and do) deteriorate without maintenance. For several years, my relationships were sustained by regular engagement in the coffee room and the pub with the same group of synthetic biologists who shared the same interests. We were all caught up in the growing momentum of the field—we felt that we were part of something new, and that this mattered.

In retrospect, these interactions were limited not only because they involved a narrow range of people but also because the emphasis on interpersonal interactions in the coffee room made it easy to overlook powerful structural forces and constraints. This points again to the importance of moving between different kinds of spaces that allow for different modes of observation, intervention, and collaboration. In chapter 5, I shift to the art studio, a room where it was possible to build on the foundations established in the coffee room to develop experimental collaborations. What was significant about these experimental collaborations is that they extended beyond the community of synthetic biologists to include artists and designers.

5 THE ART STUDIO

Thrombolites are strikingly rotund "living rocks," slowly built up over centuries in shallow water by the precipitatory activities of cyanobacteria, a microbe responsible for first introducing oxygen into the Earth's atmosphere three billion years ago. Although similar microbial constructs covered much of the early Earth, today they are only found in a handful of locations, including three lakes in Western Australia.[1] In the hot Australian summer of late November 2010, I traveled with a biological artist and a cyanobacteriologist to Lake Clifton to examine these unusual natural phenomena.

I was there thanks to a project called Synthetic Aesthetics, which was one of my defining experiences in synthetic biology. It allowed me to enter a space that I was previously unfamiliar with: the art studio. It gave me opportunities to collaborate with professional groups beyond scientists and engineers, to form new epistemic partnerships, and to develop what I am calling an emergent form of critique. The Synthetic Aesthetics project itself was not funded through the normal mechanisms but was the result of a weeklong intensive residential event called a sandpit, which I describe below because it was what led me to the art studio and because it helps explain some of the distinctive and unusual features of the project.

After the sandpit, Synthetic Aesthetics took me to Cambridge, Trento, Amsterdam, and Perth. Although I initially thought I would play an observational role in the art studio, I found this increasingly unsatisfactory. The project led me to recognize how much I had in common with artists and designers, despite not being a "maker." But the experimental collaborations that developed over the course of the project required the synthetic biologists, too. These three-way collaborations led to a shared aspiration to place a "wedge in the door" of synthetic biology to challenge the industrialization of the field—and, several years later, to a joint policy intervention. But I start at the beginning, at the sandpit.

THE SANDPIT

A "sandpit"—the British word for a children's play area filled with sand (called a "sandbox" in American English, as I quickly learned)—is a term that the UK's Engineering and Physical Sciences Research Council (EPSRC) decided to apply to one of their more unusual funding mechanisms. Sandpits are residential, competitive grant-writing retreats where participants generate project ideas over the course of a week, with funding decisions made on the final day. A sandpit called "New Directions in Synthetic Biology," jointly funded and organized by the EPSRC and the US National Science Foundation (NSF), was held in spring 2009 in Airlie House, a historic conference venue in its own landscaped grounds just outside Washington, DC. As noted in previous chapters, this was a period when UK funding councils were starting to take an interest in supporting synthetic biology, and since the US was perceived to be the leader in the field, a cross-national event was considered timely. Sandpits are a common funding mechanism for the EPSRC, but this was the first time a sandpit had been organized with the NSF, and the first time it took place in the US.

Following a call for applications, 30 people from the US and the UK were selected to attend the sandpit, 28 of whom were scientists and engineers (a political scientist and myself being the only two exceptions). During the sandpit, we were pushed to develop "transformative," cross-disciplinary, and "high risk" research proposals that were subjected to "real-time peer review" by all the other participants. The synthetic biology sandpit had approximately $10 million to distribute to successful projects, injecting the event with tension and expectation.

I attended the sandpit thinking it would be a good place for fieldwork, without anticipating that I would emerge from it with a grant. On the flight across the Atlantic, I inconclusively grappled with how I would justify or describe my science and technology studies expertise and what I could bring to the event as a social scientist.

On the first day, we were told by the EPSRC and NSF organizers that the aim of the sandpit was to "build a world-class synthetic biology community." It was clear that the event was primarily about furthering and promoting synthetic biology and that we had all been invited to be part of it on that basis. We were told that, to be funded, a sandpit project had to be creative and adventurous—it had to have a "wow factor," which was described as "something of real excitement." The purpose of sandpits was to break away from the conservativism of conventional peer review, so we were encouraged to develop projects that were outside our normal area of expertise.

The first few days involved exercises intended to help us to get to know each other and to stimulate our creativity. For example, as we entered the spacious floral-carpeted meeting room on the first day, we were each presented with a playing card (mine, which I still have, was the king of diamonds). These cards were used to group and regroup us in various different ways. At one point, we had to combine forces to produce a winning poker hand—difficult for someone like me who had never played poker. On another day, we were provided with high-quality oil paints, palette knives, and canvases and guided through a collaborative painting exercise, with specially chosen background music.[2]

Halfway through the week, after much structured brainstorming, we began developing our research projects. We were given two starting questions: "What types of problems are you hoping that synthetic biology might be able to solve?" and "What do you think is the biggest barrier to synthetic biology?" The emphasis on problems "to be solved" (by the technology) and barriers "to be overcome" (to ensure the success of the technology) was clearly based on an assumption of technological progress. Not surprisingly, one of the "barriers" that many of the participants identified was "public acceptance." This led to a team, composed only of scientists and engineers, developing a project that aimed to "embed the right kind of positive attitude in society" and induce "subtle changes of perception" about synthetic biology. I was not the only one who found this project problematic.

Others started developing scientific projects, and it was very hard for me to work out how to become part of them. I wandered dispiritedly from group to group, where some of the more senior figures had taken to giving mini-lectures. On the afternoon of the third day, an idea emerged from one of the brainstorming exercises that resulted in a Post-it note with the words "Synthetic Aesthetics" written on it. This somewhat elusive title appealed to me and two of the engineers, Alistair Elfick, my colleague from the University of Edinburgh, and Drew Endy from Stanford (organizer of the SBX.0 conference series discussed in chapter 2). We left the venue to walk around the extensive gardens and devise a project inspired by these two words.

At the end of the day, we were all expected to give PowerPoint presentations on our work in progress, but my group decided to take seriously the organizers' encouragement to push against convention by doing a dance based on the myth of the golem instead. The dance was rewarded with applause and laughter.

Over the next few days, we developed our ideas further, and we had discussions about the sublime. We decided that the Synthetic Aesthetics project should bring scientists and engineers together with artists and designers in collaborative exchanges. At this stage, the group developing the public acceptance project suggested that since we were basically doing the same thing, we should join forces. The three of us firmly disagreed, arguing that rather than being about public acceptance, our project was about exploring the intersection between art and design and synthetic biology.

Through repeated presentations, we refined the project's design. In response to real-time peer-review comments, we had to try to define beauty and defend frivolity. These activities led me down pathways and into discussions I had never anticipated at the start of the sandpit. There was an exuberance, irreverence, and playfulness to our planned project that made it popular with the other participants, and when the time came on the final day to award funding, we found out we had been successful.

What resulted from this strange and intense experience was a project that, for me, was completely unanticipated. I had not thought I would emerge from the sandpit with a grant, let alone one where I was an equal partner with the synthetic biologists involved. None of us who developed the project had prior experience in working with artists and designers, so none of us had epistemic authority over the direction of the work. This made the dynamics very different from other synthetic biology projects that I later participated in, which were much more science-led.

The fact that the project came out of a sandpit was an important part of its identity, and our shared time in this unusual space was something we reminded each other of throughout the project, particularly when it seemed to be taking us into uncharted territory. An advantage of being funded this way, rather than via a more conventional route, was that we were not tied to specific outputs and deliverables, which gave us a considerable amount of freedom.

The project we designed at the sandpit aimed to bring together the synthetic biology and art and design communities in ways that were mutually transformative, and this is how I have described it since. But looking back on our sandpit presentations and the Synthetic Aesthetics research proposal reminded me that there were also ambitions to initiate "new forms of engineering and new schools of art." And the two engineers wanted the design community to "take up, develop, and deploy the tools of synthetic biology"; they hoped to provoke a culture change in which biology became reconceived of as the kind of thing that could and should be designed. This is consistent with the synthetic biology agenda, but it laid out a path that the Synthetic Aesthetics project did not strictly follow.

THE SYNTHETIC AESTHETICS PROJECT

The project itself started later the same year. At its core were paired exchanges between six artists and designers and six synthetic biologists. We had specified in the proposal that these exchanges would be reciprocal, so they would not only involve the artists and designers spending time in the science lab—the standard way of organizing art/science interactions—but the scientists and engineers would have to spend an equal amount of time in the art studio. Because the three of us who developed the project did not have connections to the worlds of art and design, we hired Alexandra Daisy Ginsberg to help set up the exchanges. Daisy was a graduate of a program called "Design Interactions" at the Royal College of Art, which trained students to use design in an experimental and speculative manner to explore emerging technologies. In the course of this program, Daisy had developed a strong interest in synthetic biology. (She later spoke at SB7.0, the synthetic biology conference in Singapore, as discussed in chapter 2.) The project had a social scientific research component written into it, so we also hired Pablo Schyfter, an STS researcher, to work with me in documenting and analyzing the exchanges.

We advertised for participants in early 2010, and we received over 200 applications from scientists, engineers, artists, designers, architects, writers, and dancers. We selected six artists and designers and six scientists and engineers from around the world and paired them according to perceived overlaps in their orientations, interests, and expertise (apart from one pair—Oron

Catts and Hideo Iwasaki—who applied together). The pairs spent two weeks in each other's workspaces, and one social scientist (myself or Pablo Schyfter) attended each of these 12 "residencies." I visited two synthetic biology laboratories and two art studios.

The pairs were tasked with investigating design in synthetic biology, with the freedom to take their work in any direction they chose. What came out of the project was a diverse collection of work, including a bacterial plasmid represented by a 3D sound installation, a collection of speculative synthetic biology consumer products, and a boundary-troubling experiment in cheese-making using bacteria that grow on human skin (see Ginsberg et al. 2014).

THE ART STUDIO AND THE LAB

The two art studios the Synthetic Aesthetics project took me to were SymbioticA, an "artistic laboratory" in Western Australia,[3] and Mediamatic, an art and new technology studio in Amsterdam.[4] As Alex Wilkie and Mike Michael (2015) note, studios are remarkably heterogeneous spaces, making it hard to generalize about them. This heterogeneity is represented by the four other studios involved in the Synthetic Aesthetics project (which I do not discuss here) that specialized in electronic music, architecture, smell art, and industrial design, respectively.

Comparisons have been drawn between the studio and the laboratory as sites "where knowledge, material entities and practices come together in an organized, routinized and managed way in order to produce new phenomena and new knowledge" (Farías and Wilkie 2015, 1). But making this comparison is challenging for me because my time in the two studio spaces was fleeting compared to the extended period I spent in the laboratory. The exchanges were only two weeks long (due to funding constraints), and the joint projects were at their very early stages. The residents spent most of their time talking to generate ideas, having meetings with relevant specialists, attending workshops and exhibitions, and traveling to sites related to their work, rather than developing artifacts.

The pairs also spent two weeks each in the scientific partner's laboratory. I accompanied an architect to a lab in a large Edwardian building housing the plant sciences department in Cambridge, UK, and a speculative designer to a protocell laboratory overlooking the Alps in Trento, Italy. In both cases, the laboratory space was repurposed and transformed (albeit fleetingly) by the

Synthetic Aesthetics project: instead of being directed toward the production of science or technology, it became a space for the pursuit of an art/science collaboration.

The scientists who had applied to be part of Synthetic Aesthetics were obviously a self-selecting group who were keen to engage with artists and designers and to welcome them into their labs. In both Cambridge and Trento, these labs were not particularly spacious, and it was not just the paired artist/designer who had to be hosted but also an STS researcher (either myself or Pablo Schyfter) and Daisy Ginsberg, who attended all the residencies and documented them with photos and film. There were occasions when the social scientists and artists/designers in these laboratory spaces outnumbered the scientists.

To help develop ideas for their joint Synthetic Aesthetics work, the artist/designer was introduced by their paired scientist to relevant laboratory techniques, such as BioBrick assembly and lipid vesicle construction, and to relevant equipment, which in both cases included specialized types of microscopy. I initially observed their interactions, which was the role I had written for myself in the grant. But I quickly realized that cross-disciplinary idea formation was a delicate process that did not always benefit from being watched. Daisy also took an observational role, but her observations were interestingly different from mine—for example, she noted the beauty and simplicity of some of the lab equipment and was struck by the ways that members of the laboratories had chosen to personalize their workspaces. Daisy did not restrict herself to observation, however, and actively participated in the pairs' idea generation process on the basis of her expertise in art and design.

After spending time together in the lab, the pairs moved to the studio. I accompanied the speculative designer and the Trento-based protocell scientist to Mediamatic in Amsterdam. For logistic reasons, I did not attend the other leg of the Cambridge-based scientist's exchange at an architecture studio in New York.[5] Instead, I went to SymbioticA at the University of Western Australia, where Hideo Iwasaki, a cyanobacteriologist from the University of Waseda in Tokyo, was paired with the Australian-based biological artist Oron Catts (whose talk at SB7.0 was discussed in chapter 2).

Even taking into account the heterogeneity of art studios, both SymbioticA and Mediamatic are atypical. Neither are places where one would find a lone painter at their easel. The people who work in both are concerned with reaching outside the safety of the studio into the worlds of science and technology, attempting to create new spaces for critical exploration. They colonize corners of other buildings and squat temporarily in rooms that do not belong to them. A feature of both these studios is that they lead on to other places.

SYMBIOTICA

SymbioticA occupies a unique institutional niche as "an artistic laboratory dedicated to the research, learning, critique and hands-on engagement with the life sciences."[6] It is embedded within the University of Western Australia's School of Anatomy, Physiology, and Human Biology. SymbioticA has become a place of pilgrimage for aspiring biological artists and has also hosted several social scientists and humanities scholars.

Hideo Iwasaki and I arrived at SymbioticA at the same time, and Oron Catts gave us a tour. The main office was a cluttered attic room with many books, desks, a sofa, and a plastic flying pig suspended from the ceiling (referencing one of Catts's most famous works, "Pigs Wings").[7] This room, we were told, provided a safe space for artists. There was also a small laboratory space, with a sheep's head placed incongruously in the fume cupboard. Oron told us they had initially squatted in the lab space, and it was eventually given to them.

Prior to founding SymbioticA in 2000, Oron and partner Ionat Zurr had conducted their artistic work in laboratories belonging to scientists, but they felt constrained by the relationships of hospitality and obligation that were required (constraints I also experienced during my time in the lab), so they decided to set up their own space. This was not a straightforward venture, and SymbioticA had to raise its own funding until 2006 when it was given a budget line by the university. When I arrived in 2010, it had recently been recognized as a research center, which Oron stressed was very important, because he saw it as an acknowledgment that artistic research was as valid as any other kind of research. Another development was that the artists were given access to other shared labs in the School of Anatomy, which was where most of their work now took place.

Lab access was crucial to the biological artists at SymbioticA because their practice involves the direct manipulation of living systems, using the very same tools and materials as those used by scientists and engineers but for artistic rather than scientific purposes. As Catts and Zurr (2018, 41) explain, "Biological artists use biotechnology as their palette and medium, working both technically and conceptually with life." They see this experiential involvement as a political act, which involves "breaking down dominant discourses, dogmas and metaphors to reveal new understandings of life" (Catts and Zurr 2008, 140).

There are similarities to hackerspaces and community laboratories here because these are also spaces where the tools of science and technology are used for purposes that may diverge significantly from those of scientists and engineers (Meyer 2013). And the artists at SymbioticA do contribute to the democratization of the life sciences by helping build a community of artists who are skilled in conducting laboratory work (Catts and Cass 2008). Since the early 2000s, they have organized workshops that provide an introduction to laboratory techniques, where participants are taught how to make do-it-yourself alternatives to expensive scientific equipment (Vaage 2017). However, their interest in subverting the tools of science and technology for critical purposes distinguishes their work from the more educational and entrepreneurial activities that often take place in hackerspaces (Vaage 2016).

The reason Oron put such an emphasis on actually doing laboratory work and wanted to enable other nonscientists to do so, too, was because he thought this enabled a profoundly critical engagement with the life sciences, which could not be achieved in other ways. He mildly chastised me (and social scientists more generally) throughout my stay for not getting my "hands dirty" by actually manipulating biological entities.

ORON AND HIDEO'S PROJECT

Because he had worked in labs for many years, Oron had extensive technical and scientific knowledge, and Hideo, the scientific side of the partnership, was also a practicing artist, blurring the boundaries between this art/science pair. They decided to focus their Synthetic Aesthetics work on Hideo's area of expertise—cyanobacteria—by engaging closely with its qualities as a living organism. This approach is characteristic of Oron's work more generally. He wants "to celebrate what is unique to living systems . . . the imperfections, the importance of variety and difference, the moist, leaking and boundary-defying tendencies" (Catts and Zurr 2018, 52). For these reasons, he argues strongly that the "engineering mindset" should not be applied to living things (Catts and Zurr 2014). Hideo was well matched with him in this sense, since he was not invested in the engineering agenda of synthetic biology.

FIGURE 5.1
Thrombolites at Lake Clifton, 2009. *Source*: Photograph by Perdita Phillips.

The pair started their joint work by noting that cyanobacteria operate at multiple timescales simultaneously. They have fast metabolic processes like any other microbe. They are also one of the simplest organisms to have circadian rhythms, so they operate on a day–night cycle. But at a totally different scale, as mentioned at the start of this chapter, cyanobacteria were the organisms responsible for converting the Earth's atmosphere to oxygen and making possible life as we know it. For these reasons, we can conceive of cyanobacteria operating on a geological as well as a biological timescale. The geological timescale stretches from the beginning to the end of the Earth and puts all human activities in humbling perspective.

Inspired by the multiple temporalities of this organism, Oron and Hideo decided to focus on the use of time as an instrument of humility in synthetic biology. This is why we made the 100-kilometer road trip from Perth to Lake Clifton to visit the thrombolites (see figure 5.1).[8] As living reminders of the origins of life on Earth, these distinctive formations connected us to the deep past in a vertiginous manner. This was a place to reflect on time and on the history of biology as we know it, challenging us to expand the frames within which synthetic biology is normally considered.

This is an example of how SymbioticA as an art studio opened up to other spaces—and in this case, to a distinctive outdoor space that clearly was not a room in the sense of being separated from the elements by purpose-built walls. However, I do think Lake Clifton could be understood as a room in the second sense discussed in the introductory chapter: as an "opportunity, scope, or opening for something." None of us belonged there, but it provided an opening for experimentation and exploration of the limitations of synthetic biology. This was one of the moments in Synthetic Aesthetics in which I shifted from observer to collaborator, being compelled to think about synthetic biology in new ways by the environment and my companions.

MEDIAMATIC

My second art studio is Mediamatic in Amsterdam, where Sheref Mansy, the scientist from Trento, spent two weeks with Sascha Pohflepp, an artist and speculative designer. Mediamatic is an arts center focused on new technological developments. It was founded in 1983, driven by the question: "How are new media changing our society?" Its focus was on media technology in the 1980s, interactive media in the 1990s, and social media in the 2000s. More recently, it has started to develop an increasing interest in biotechnology and sustainability.[9] When we visited the site in 2010, it was notably different from SymbioticA, with rows of people working on outsized computer screens in an ordered, open-plan, white-painted office space occupying a modern building (which had previously been a bank) in the city center. Sascha, Sheref, Daisy, and I met on the disused trading floor for extended discussions, but we spent the majority of our time traveling to meet artists, designers, and curators in Amsterdam who had an interest in working with biology.

Mediamatic hosts an active program of public events, and the culmination of Sascha and Sheref's residency was an evening salon where they both spoke alongside a body artist and a philosopher. In fact, public events were a feature of all the Synthetic Aesthetics residencies and of the project as a whole, demonstrating the permeability of the boundaries of the art studio. They took place in a diversity of places that were open to the public, including galleries and museums—places that do not belong to scientists and engineers and can be sites for emergent encounters, places that in a longer book would deserve their own chapters. Notably, for most of the artists and designers involved in the project, public discussion was not regarded as an add-on but as integral to their work and a necessary part of the process of exhibiting it. Although discussion was admittedly limited to a self-selecting public—that is, people who were aware of and chose to attend these events—the art studio does seem to provide an opening to interested publics in a way that distinguishes it from the other rooms discussed in this book.

SASCHA AND SHEREF'S PROJECT

Like Oron and Hideo, Sascha and Sheref decided to explore the distinctive properties of living things in their joint project. Sheref was originally trained as a chemist, and his research involves attempting to create simple living "protocells" from nonliving components. This approach to synthetic biology is more concerned with investigating the nature of life than with the engineering of existing biological systems.[10] Since Sheref wanted to create life in the laboratory, he needed a working definition of it, and one of the most prominent definitions is from NASA: "a self-sustaining chemical system capable of Darwinian evolution" (Benner 2010). This led Sascha and Sheref to focus their work on evolution. They reasoned that if evolution was a defining feature of life, and if synthetic biology aspired to build living machines, then these living machines would have to evolve. But this pointed to a tension at the heart of synthetic biology because a machine that evolved would not possess the stable, predictable properties we expect of our machines. This, they argued, had knock-on implications for design in synthetic biology because it would necessarily involve "Designing with Darwin" (Mansy and Pohflepp 2014, 255) and a concomitant loss of control. An advantage of evolving machines, however, was that they would be able to evolve along with their environments, making them more sustainable in the longer term than the machines we use today.

Sascha and Sheref's work was primarily conceptual, and their outputs resonate with and draw on the STS literature (see Mansy and Pohflepp 2014). But it is significant that they highlighted the distinctive features of biological systems to explore novel directions for synthetic biology. In fact, a notable feature of the work produced across the Synthetic Aesthetics project was that it involved designing with a sensitivity to the capacities *of* biology rather than imposing designs *on* biology. This was a subtle shift away from one of the objectives put forward at the sandpit, which was that biology should be reconceived of as the kind of thing that could and should be designed. The Synthetic Aesthetics residents showed that biology could only be designed on its own terms. As noted in chapter 2, the recognition that complex, contingent, and unpredictable biological systems do not always succumb to engineering can be the beginning of a more normative position because it shows that there are alternative ways of engaging with the biological world that do not align with dominant instrumental rationalities. The art studio seemed to lend itself to the development of such alternatives.

ALTERNATIVES AND POSSIBILITIES

This is perhaps not surprising, since many accounts of art and design describe these activities as inherently generative of new possibilities by challenging what is taken for granted (Dixon 2009), resisting the consensual way in which a situation is presented (Michael 2012), or making the world strange (Catts 2018). This is often because of the speculative character of this work, which "opens up a multitude of worlds-to-be" (Johung 2016, 182). Chris Salter and colleagues (2017, 139–140) argue that it is precisely because artists and designers "work in speculative modes of inquiry" that they "are not necessarily beholden to established epistemological frames, methods, and practices."

Not all the artists and designers on the Synthetic Aesthetics project saw themselves as engaged in speculation, but those who did aligned themselves with the work of Fiona Raby and Anthony Dunne, who founded the Design Interactions course at the Royal College of Art. They have been key in articulating speculative design as an approach that offers "an alternative to how things are" (Dunne and Raby 2013, 35) through the production of novel artifacts. Such alternatives are not necessarily preferable, but they loosen "reality's grip on our imagination" (Dunne and Raby 2013, 3) and allow the liberating question: "what might be?" (Sims 2017, 443). This question, this sense of possibility, was something that came out of all the Synthetic Aesthetics work.

Challenging dominant visions and showing that there are other possibilities is, as I will argue in chapter 6, core to how I conceive of STS. The Synthetic Aesthetics project showed me that this agenda was one I shared with the artists and designers. This was unexpected but somewhat revelatory and changed my approach to the project. It meant that I could think of the artists and designers as fellow travelers and see us as being involved in a shared investigation. It also meant that I could reconceive of my role in the project from an observer who documented and analyzed the exchanges (a role that had become increasingly unsatisfactory for me as the project had progressed) to a collaborator involved in the coproduction of knowledge.

There are, of course, continuities here with the discussion of epistemic partnership and thinking *with* others in the coffee room, with the significant difference that the epistemic partnerships in the art studio were not limited to scientists and engineers. As discussed in chapter 4, epistemic partnerships can lead to experimental collaborations, which require an openness to the unexpectedness of different ways of seeing the world. And the art studio is arguably the ideal place for experimentation because of the "experimental and open-ended character of arts practice" (Ingold 2013, 8) that can be harnessed in collaborative work (see also Marres, Guggenheim, and Wilkie 2018). The motivation for experimental collaboration is strengthened if, as I have suggested, art and design share with STS the aspiration to challenge current framings and elicit alternatives.[11]

The Synthetic Aesthetics project provided conducive conditions for experimental collaborations. I found these valuable because they led to what I am calling an "emergent form of critique," which I argue can expand the critical capacities of STS. This critique is "emergent" because it grows out of the collaboration itself—it is not possible to predict in advance what form it will take. Such an emergent form of critique is not specific to interactions between social scientists and artists and designers; in fact, in Synthetic Aesthetics, it also involved scientists and engineers. Unlike conventional understandings of critique, it is not about one group applying their critical tools to another; instead, it requires the coming together of different perspectives. What is generated is then more than (and different from) anything that could result from a single discipline: an emergent form of critique creates something new.

Fitzgerald and Callard (2014, 19) similarly maintain that one of the reasons for engaging in interdisciplinary research is because it can "produce something new in the world," with the caveat that such novelty only arises from certain forms of interdisciplinarity. Andrew Barry and colleagues (2008, 42) usefully distinguish between interdisciplinarity that follows the logics of accountability (to society) and innovation (which aims to further economic growth) and interdisciplinarity that follows the logic of ontology, which can lead to "new objects and practices of knowledge." It is the latter type of interdisciplinarity that I think was exhibited in Synthetic Aesthetics. The novelty that emerges in these situations "cannot be explained away as the consequence of pre-existing factors or forces" but instead serves to "open up the space of future possibilities" (Barry, Born, and Weszkalnys 2008, 25). So, novelty is not valued in and for itself, but for the alternatives it brings to light.

THE WEDGE IN THE DOOR

To make this discussion more tangible, I will briefly describe my most significant experience of an emergent form of critique in the Synthetic Aesthetics project, which developed from interactions between the core organizing team (made up of myself, engineers Drew Endy and Alistair Elfick, the artist/designer Daisy Ginsberg, and Pablo Schyfter, the other STS researcher).

Three years into Synthetic Aesthetics, we were planning a coedited book on the project during one of our weekly video calls and attempting to articulate what we wanted this book to achieve. Together, we came up with the idea that it should be a "wedge in the door." We united on this metaphor because we all wanted the interdisciplinary interactions initiated by the project to stop synthetic biology from closing, from becoming narrow and myopic. Drew and Alistair were engineers who had been drawn to working with biology because of its distinctive features, and they were frustrated at moves to use synthetic biology to simply produce "drop-in" replacements for petrochemicals—to just make more of what we already have. Instead, they thought living systems should be harnessed in a manner that was sympathetic to their capabilities (Elfick and Endy 2014). Daisy, Pablo, and I were interested in challenging the dominant futures imagined for synthetic biology and in this way demonstrating the diversity of possible paths that could be taken. We all coalesced around the idea that Synthetic Aesthetics could act as a wedge in the door—an attempt to prevent the unimaginative industrialization of biology.

I see this as an example of an emergent form of critique because it arose from our collaborative work and was significant for all of us. It was behind a more explicitly normative intervention we later made (which I describe below). One of the reasons the metaphor of the wedge in the door worked for us was because of its brute physicality: The door on synthetic biology was closing, and the hardback picture-filled book that we were writing together would attempt to stop it from doing so. As Drew put it in a published interview: "Synthetic Aesthetics is meant to be a political doorstop that says 'there's a different way to think about the future of biotechnology' and you can't shut that out" (see Kieniewicz 2014).

The fact that a door is something that closes on a room is, of course, relevant to this book. The metaphor of the wedge in the door demonstrates a point that has been touched on in previous chapters: It is not only the room that is important but also how easy it is for others to enter and leave. Opening a room to artists and designers is also opening it to the alternatives and possibilities their work gives rise to.

POST–SYNTHETIC AESTHETICS

The book that resulted from the project in 2014 was motley and interdisciplinary with 20 different contributors, over 100 images, and jointly authored chapters by the art/science pairs. It has almost certainly been used as a literal doorstop, although it is not yet clear whether it has succeeded as a metaphorical one. As I come toward the end of this chapter, I turn to some of the more problematic ways in which the book has been interpreted, because these interpretations reflect both the constraints of the Synthetic Aesthetics project and the risks of bringing art and design into engagement with synthetic biology.

The project team had made efforts to ensure that the *Synthetic Aesthetics* book (Ginsberg et al. 2014) had a critical edge: We jointly wrote two chapters that challenged the current direction of the field, and a chapter by Oron Catts and Ionat Zurr argued strongly against the engineering of living things. The other chapters presented a whole spectrum of different, sometimes ambivalent, often conflicting views on synthetic biology and its imagined future. Some reviewers recognized our critical intentions and noted that the book challenged the dominant assumptions and motivations of the field (Ball 2014). However, according to a few critical commentators, the project was tarnished from the outset because it was funded by two national science research councils (the EPSRC and the NSF), placing us in relations of obligation (even if implicit) toward these funders. It was also considered problematic that two of the project's investigators—Drew Endy and Alistair Elfick—were well-known figures in synthetic biology. One article by a social scientist that commented on synthetic biology broadly, and Synthetic Aesthetics specifically, concluded that "engagement with humanities, social sciences and arts has been co-opted for legitimization and science communication" (Hagen 2016, 201). As noted in chapter 2, the most damning critiques of social scientific engagement in synthetic biology seemed to come from other social scientists.

The accusation that art and design are merely used as tools to help make science more publicly palatable is a familiar one. And this is not always a misdirected criticism. Georgina Born and Andrew Barry (2010) show how many art/science programs follow logics of accountability and innovation and are funded because of their assumed contributions to scientific and economic development. Jaqueline Stevens (2008) maintains that much of the motivation behind DNA art is to improve public attitudes toward genetics, and Deborah Dixon (2009, 421) shows how bioart "is applauded as an exercise in public information awareness concerning the revolutionary potential of biotechnology itself." This can be the interpretation even if it is completely opposed to the intentions of the artists and designers involved. Catts and Zurr (2018, 45) point to the danger of artists "being part of the process of creating public acceptance for the new technologies they are exploring, even when doing so from a critical perspective."

Although these challenges were not unique to Synthetic Aesthetics, a misrepresentation of the project in a prominent policy report was particularly troubling. *Biodesign for the Bioeconomy* was published in 2016 by the UK Synthetic Biology Leadership Council (SBLC), a government-appointed group set up in 2012 "for strategic coordination of UK synthetic biology." This council was cochaired by a government minister and is discussed further in chapter 7.[12] The report's aim was to push forward the industrialization of synthetic biology. Aside from the main text, there were a series of boxed "case studies" highlighting significant work in the field. Synthetic Aesthetics was selected as one of the case studies, although none of us from the project were consulted in advance. I was taken aback when I read the description of our project in the final report: "Synthetic Aesthetics, an international project led by Edinburgh and Stanford Universities, brought together artists and designers with scientists, to beautify or better communicate the science of synthetic biology" (SBLC 2016a, 24). I alerted the others on the Synthetic Aesthetics organizing team, and we were all somewhat dismayed. Since the sandpit, we had struggled against the idea that the aim of the project was public outreach; we had even included a sentence in the *Synthetic Aesthetics* book that read: "Some people assume 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" (Ginsberg et al. 2014, xviii).

The five of us on the Synthetic Aesthetics organizing team decided to write an open letter to the SBLC objecting to this misrepresentation of the project. We all agreed on the points that needed to be made. We emailed the letter to all the members of the SBLC and made it publicly available on the Synthetic

Aesthetics website. We drew on the repeated use of the word “design” in the report, which it used as a proxy for the manipulation and commercialization of living things; this diverged significantly from our exploration of the potential of art and design to open up the field. We argued that “the urgently needed interdisciplinary conversation about what good design constitutes in synthetic biology, which the Synthetic Aesthetics project aims to provoke, has nothing to do with beautification and better communication of the science. To represent our work as such is completely contrary to our objectives and can only be detrimental to the future of synthetic biology.” Responding to the narrow focus on the industrialization of synthetic biology in the report (and bolstered by our “wedge in the door” metaphor), we continued: “Design does not only serve industry and economic growth; good design enables citizens and society and should serve the common good.” We went further to say that it is “crucially important that strategic decisions about “better” design should not be limited to a select group of experts with a controlling stake in the technology. We observe that the membership of the UK Synthetic Biology Leadership Council may be deficient in this regard.”

In response to this letter, the SBLC did change the report. In the version that is now publicly available, the text on Synthetic Aesthetics is ours. It says that the project led to “consideration of futures that might transcend current industrial framings” (SBLC 2016b, 24).

One of the conclusions that can be drawn from this incident is that working with artists and designers in scientific contexts always carries with it the danger of being accused of attempting to make the science more publicly acceptable. What is also significant, however, is how this misrepresentation of the project actually allowed us, the project team, to raise broader issues about who should have a voice in the shaping of synthetic biology. Our objection to the restricted membership of the SBLC was an argument for the involvement of a greater diversity of perspectives in the field. One of the synthetic biologists even suggested that we should set up a rival “shadow leadership council” involving people from the humanities, social science, art, and design. The discussion quickly became about more than beautification, and it showed how the art studio can become political. Over the course of Synthetic Aesthetics, the project team had come to share a normative agenda, articulated as the wedge in the door, which we mobilized for critical purposes to object to the narrowing of the field. Our collaboration allowed us to do more than we could have done individually and emboldened us to make a critical intervention together.

I want to step back at this point, however, because I have slipped easily into using "we" (as I did earlier in the description of the sandpit). Of course, this is what should happen during a truly collaborative venture. But I think it is suspicions of this use of "we" that are behind some of the criticisms of Synthetic Aesthetics, particularly because this "we" includes leading proponents of synthetic biology—albeit those who wanted to change its course. Although I felt great solidarity with the project team, and my experience was one of genuine epistemic partnership, it remains the case that the aim of the sandpit out of which the project arose was to promote the development of synthetic biology. In this light, it is perhaps not surprising that the project was interpreted as beautification and science communication, or that what I thought of as our subversive interventions—which particularly pleased me because they also involved synthetic biologists—were just seen as part of an elaborate "window dressing exercise" (Catts 2016).

Contamination, complicity, and the domestication of critique are themes from previous chapters that clearly arise again in this project, which involved close collaborations with synthetic biologists. But these collaborations enabled the project to highlight the critique from *within* the field of its prevailing trajectories.[13] The project also demonstrated the diversity among the scientists and engineers working in synthetic biology. For example, both Hideo and Sheref were ambivalent about the engineering approach to synthetic biology, and their work foregrounded some of its core challenges.

SCIENCE AND TECHNOLOGY STUDIES IN THE ART STUDIO

Synthetic Aesthetics has come to define what I think of as successful experimental collaboration in synthetic biology. However, as I have shown, it was not free of discomforts and compromises, partially because it required collaborations and negotiations between three different groups: scientists and engineers, artists and designers, and STS researchers. Because of these three-way interactions, this chapter does not straightforwardly represent an STS researcher's experience in the art studio. Of course, entering the art studio *without* scientists and engineers is a route other social scientists have taken (Wilkie and Michael 2015), but this particular route was precluded by the setup of Synthetic Aesthetics. However, the project's particular organization did have the advantage that it compelled the synthetic biologists to leave their workspaces and enter the art studio, a room where they were also outsiders.

Although the problematic ways in which the project was received and interpreted by some commentators must be acknowledged, one of its strengths was that it was not clearly an art and design project, a synthetic biology project, or a social science project. The distinctive characteristics of this three-way collaboration meant we could develop forms of critique that exceeded our different disciplinary perspectives. From the sandpit to the thrombolites to the wedge in the door, the whole experience of Synthetic Aesthetics was for me marked by unexpectedness and a genuine openness to cross-disciplinary experimentation. This owed much to the nature of the somewhat unconventional art studios I spent time in, which opened up to spaces beyond themselves. What I found most revealing, however, was how much I shared with the artists and designers. Like them, I wanted to bring alternatives to light, to show that things could be otherwise. This realization meant that I could reconceive of my role in the project from an observer to a participant in a shared endeavor.

But there was one way in which, as a social scientist, I was more of an outsider in the art studio than the synthetic biologists: I was not a maker. The fact that I was not interested in getting my "hands dirty" separated me from the other two groups. Like the scientists in the synthetic yeast lab who were keen that I carry out a miniprep, the artists and designers thought I should get more involved in the practical work. They even recommended that I approach laboratory studies as an artist would, by bringing my own wet-lab project to the lab (and on reflection this may be the best way to do a type of laboratory studies that is not primarily observational).

In their active engagement with the materiality of synthetic biology, the artists and designers in the Synthetic Aesthetics project demonstrated the value of going beyond discursive, textual ways of intervening in science and technology (see also Zuiderent-Jerak 2015). But my interactions in Synthetic Aesthetics were not centered around the construction of tangible artifacts. The experimental collaborations that I was part of were more about the process of working together than the artwork produced. And, as noted above, the short-term nature and nascent stage of the art/science exchanges meant that the development of ideas, rather than artifacts, was most important to the residencies.

The development of ideas is an area where STS can clearly contribute. And this takes me to an issue I was wrestling with throughout the project: What did I bring to Synthetic Aesthetics as a social scientist? In a sense, this chapter is an attempt to address this question, and is something that an artist, designer, or synthetic biologist would probably not aspire to write. My tentative answer is that I attempted to make sense of the Synthetic Aesthetics project, and the collaborations that arose, and to distill what I found valuable about it in a way that extended beyond the specific project and could be taken forward by other researchers in different contexts.

What I gained most from the project was that it allowed me to better articulate what I wanted to do as an STS researcher by recognizing that I shared with the artists and designers an aspiration to expand the range of possibilities that could be imagined in synthetic biology. In fact, it was only by participating in the project that I came to clarify this aspiration. I am not intending to make a bold claim here about the purpose of art, or the purpose of STS for that matter, but this recognition of a shared agenda was invaluable in allowing me to formulate what I aimed to achieve in synthetic biology more broadly, across all the different rooms discussed in this book. Although I have put this in individual terms, the work of challenging existing framings and opening up novel possibilities is necessarily collaborative and cross-disciplinary, as I will argue in chapter 6. And it was the collaborative and cross-disciplinary nature of Synthetic Aesthetics that made it rewarding—even, at times, transcendent—and left me with a lasting enthusiasm for this type of work.

6 THE BIOETHICS BUILDING

In synthetic biology contexts, I am often mistaken for a bioethicist. This is not something I am comfortable with—it is not how I am trained or how I approach science and technology—so I resist this designation. This has occasionally led to difficulties. For example, I was telephoned by a researcher from the UK's national TV program *Newsnight* because they were making a feature on synthetic biology and wanted a bioethicist to comment on the field. As soon as I explained I was not one, the call was quickly brought to an end. I did not fit the bill, and they had others on their list. I have also arrived at conferences to be told that my talk is expected to stimulate a lively ethical debate; objecting that I am not a bioethicist in this context is simply regarded as unhelpful. On other occasions, scientists have ignored my self-definition as a social scientist and introduced me as a bioethicist, even inserting the word into an introductory text I have prepared for them in advance.

One of the reasons I object to the label "bioethicist" is because I feel it comes with the assumption that I am there to judge or evaluate the science, which is not something that I see myself as doing. I am aware that such judging or evaluating is not what many bioethicists see themselves doing either, so my reluctance probably owes more to the assumptions scientists and engineers have about bioethics than to the practices of bioethics itself. And it is the case that I am increasingly wanting to make normative interventions into my field of study, as well as dealing with expectations from scientists, engineers, and research funders that I should be doing so.

I start this chapter by exploring these expectations and show how they can often be traced to the idea that the epistemic and the normative can be easily separated. I then discuss how, despite not identifying as a bioethicist, I have been involved in several bioethical initiatives, which meant that I spent time in two notable bioethics buildings. I focus primarily on my involvement in a Nuffield Council on Bioethics working party and discuss the report we produced together on emerging biotechnologies. This report was influential on my own thinking and my attempts to articulate a version of normativity that is consistent with science and technology studies. I call this version of normativity "otherwising." I show how I ground this in the STS literature and explain why I embrace this approach. I end by reflecting on the interdisciplinary space that characterizes the bioethics building and conclude that it can be an inclusive one, a place where STS researchers can contribute.

THE EMPHASIS ON ETHICS

In previous chapters, I have noted that STS researchers are often invited to be involved in synthetic biology on the grounds that they will investigate its ethical, legal, and social implications (ELSI). Although the "S" for "social" is present in the acronym, one of the dominant expectations of ELSI research is that it will include an ethical dimension.[1] And an ethical contribution to a scientific project is often valued and comprehended by scientists, engineers, and research funders in a way that a more epistemically oriented social scientific contribution is not. Many synthetic biologists will pay for STS researchers to do what they regard as the ethics but not to do laboratory studies (which has now become something of a luxury, as discussed in chapter 1). As a result, in synthetic biology in the UK at least, STS researchers are often finding themselves in roles that would perhaps better fit bioethicists.

But why is there an insistence from scientists and research funders that the "ethical" issues need to be addressed? This could be seen as an enlightened recognition of the normative dimensions of scientific work and the limits of technical expertise. But it can be interpreted in other ways too. There is a frisson in needing to have guardians of morality present at all. An implicit logic dictates that if synthetic biology is contentious and potentially ethically problematic, it is therefore deserving of attention and most probably funding. As Nordmann and Rip (2009, 273) argue in respect to nanotechnology, "When philosophers and other researchers discuss the ethical aspects of nanotechnology, they lend further credibility to its power and promise," meaning that the "most visionary promoters of nanotechnology are therefore the first to call for ethical consideration of the predicted applications."

The main problem that I have with the bioethicist role, however, is that it often reinforces the view that the science can be separated from its social and ethical dimensions, an issue that has arisen in earlier chapters. STS research has consistently challenged this distinction between the epistemic and the normative, between facts and values (Hilgartner, Prainsack, and Hurlbut 2017). This makes it problematic for STS researchers to be tasked with carrying out normative work in separation from epistemic analysis. And it leads to one of the central criticisms of the ELSI framing: that it treats the social and ethical "implications" as downstream and detached from the scientific research (Rabinow and Bennett 2012). If the facts are left to the scientists and the values are left to the ethicists, this can result in a division of labor that does not disrupt any of those involved (Felt 2018). As Jack Stilgoe and David Guston (2017, 857) put it, "the growth of institutions of risk and ethics governance follows a narrative of responsibility with which the scientific community has grown comfortable." This is a key reason why scientists and research funders want the "ethics" to be dealt with and why STS researchers often find themselves being pushed into this siloed realm. To be separately normative fits with the status quo and does not disturb the established boundaries of science.

I want to engage with the very same topics that interest scientists and engineers, however, treading on their epistemic toes. For example, as outlined in chapter 1, I am interested in the ways in which evolution challenges engineering aspirations in synthetic biology, a topic that is a central concern to the synthetic biologists themselves. Of course, this involves analyzing the values and assumptions that drive those engineering aspirations, as is consistent with the refusal to separate the epistemic from the normative. Engaging with the content of the science in this manner is in some ways more destabilizing than doing the requested normative work because it challenges the division of labor between facts and values.

For all these reasons, I am uncomfortable being referred to as a bioethicist. But I am equally uncomfortable when I am told that the ethical is missing from my analysis. I have been a speaker at several events where it was clear that members of the audience felt that the ethics had not been addressed and that this was troubling. An example was a talk that I (incongruously) gave at the World Economic Forum at Davos in 2015 in a session on synthetic biology, as the only social science speaker alongside three synthetic biologists. I gave a presentation about the social values that underlie technological choices, drawing on Langdon Winner's (1980) classic study of the bridges over the roads in Long Island to show how values can be built into designs. The story goes that the bridges were built so low that buses could not pass underneath them, meaning that only wealthy people who owned cars could travel to the parks and beaches outside New York City. I am aware that this tale is not as straightforward as it seems (see Woolgar and Cooper 1999), but the point I wanted to make is that technologies enable some things and prevent others, and they embody certain values. I built on this example to show how ideas about open source were being incorporated into the design of standard biological parts in synthetic biology. I argued that such design decisions would have an influence on the future of the field and on who could be part of this future.

After the talks had finished, one of the audience members, a scientist from the UK, was eager to step in to reassure the international businesspeople in the audience that they did not need to be concerned about synthetic biology because "we have people looking at the ethics." I was rather taken aback by this comment, since it showed that the points I had made about values and choices underlying synthetic biology designs had clearly not been recognized as being ethical contributions. And this was not an isolated experience—a public event on the *Synthetic Aesthetics* book (discussed in chapter 5) resulted in similar concerns among some audience members that the ethics had not been addressed. My response to this problem is not to retrain as a bioethicist but to try to articulate the normativity of what I do more convincingly, which is my focus in the second half of this chapter. But first, I step further into the bioethics building itself by discussing two buildings that I temporarily occupied.

TWO BIOETHICS BUILDINGS

Despite my problems with being labeled as a bioethicist, I have been involved in several bioethical initiatives. Most notably, I was a member of the working group on Ethical Issues in Synthetic Biology at the Hastings Center from October 2011 to March 2013 and the Nuffield Council on Bioethics working party on Emerging Biotechnologies from January 2011 to December 2012.

As part of these groups, I was invited to enter two distinctive buildings. The Hastings Center occupies a grand manor house in upstate New York. It is known as the birthplace of bioethics, making it a place of pilgrimage for some. The Nuffield Council on Bioethics, the closest thing the UK has to a national ethics body, is based in an elegant Georgian townhouse in central London. The chapters in this book so far have been about rooms, so it is significant that I am not talking about a room in either of these cases. Both organizations were independent and occupied buildings that were self-contained and originally private residences of the well-to-do. These buildings represented autonomous ethical discussion, institutionally separated from the science.

The two spaces were geographically far apart, but they had many similarities. In being stand-alone and dedicated to bioethics, both had an authority and an ability to command respect and the contributions and commitment of senior figures. In both spaces, the groups benefited from the participation of scientists and engineers who were willing to reflect on their research in its broader epistemic and social context, enriching the debate. These buildings were not scientific institutions, and scientific voices did not dominate, but I nevertheless felt somewhat out of place in both of them, with a feeling of being on someone else's turf.

My involvement in both spaces was as a member of a working party, so my presence in these buildings was temporally limited to a series of one- or two-day meetings over several months. I could not choose to enter these buildings whenever I wanted, but when I was there, I was invited, expected, and legitimate, signing my name in the visitor book in the Nuffield entrance hall or being driven to the Hastings Center along forested highways. In both cases, the space we met in was a formal one, meaning that my experience in these buildings was not as collegial as in the conference room or as intense, because the meetings were spread out over many months. The boundaries between the academic and the personal were not blurred to the extent they were in the coffee room. In both buildings, the working parties developed a shared understanding of the issues and, in the Nuffield case, coauthored a report.

My focus in this chapter will be the Nuffield Council on Bioethics, but I will start with a brief description of the Hastings Center, which was the first formal institution in the world to study ethical problems in medicine and biology (Callahan 2012). Founded in 1969, it occupies a mid-nineteenth-century estate resting in its own grounds overlooking the Hudson River in upstate New York. Its library doubles as a meeting room where the working group on Ethical Issues in Synthetic Biology gathered. This group was interdisciplinary and diverse, including scientists, engineers, social scientists, representatives from civil society organizations, philosophers, lawyers, and bioethicists—both traditional and less so. The meetings were oriented around prepared presentations from group members, each followed by generous time for discussion. The discussions were rich, but the meetings did not attempt to achieve consensus or to produce a joint document. The final output was a journal article authored by the Hastings Center organizers (Kaebnick, Gusmano, and Murray 2014a), which was written within a disciplinary bioethics frame. The article was followed by short responses written by members of the group (Kaebnick, Gusmano, and Murray 2014b).

THE NUFFIELD COUNCIL ON BIOETHICS

Following this brief excursion to the Hastings Center, I now head back across the Atlantic and to the Nuffield Council on Bioethics, in Fitzrovia in central London (see figure 6.1). A painting of William Morris (later Lord Nuffield), philanthropist and carmaker, hangs in pride of place in the ground-floor room that is used for sandwich lunches and tea breaks. Most famous perhaps for the Morris Minor car, Morris set up the Nuffield Foundation, a charitable trust that launched the Nuffield Council in 1991 following unsuccessful calls for the UK government to set up a national bioethics body in the late 1980s (Shapiro 1995). The council is funded by the Nuffield Foundation, the Medical Research Council, and the Wellcome Trust (Shapiro 1995). The spacious first-floor meeting room has a portrait of British bioethicist and council founding member Onora O'Neill looking down on the proceedings. The interactions the working party had in this civilized space were marked by well-chaired debate, with formal name signs laid out on the table in front of every participant. Nuffield working parties are always disciplinarily diverse; this group was chaired by a political scientist and its members included another STS researcher, a patent lawyer, a historian, a physicist, an engineer, an economist, a card-carrying bioethicist, and members of the Nuffield Council's dedicated secretariat.

The Nuffield Council on Bioethics is the space I focus on in this chapter because my engagement with this working party was more frequent and intense than it was with the Hastings Center and also because the output was a cowritten report in which we—the members of the working party—had to

FIGURE 6.1
The building occupied by the Nuffield Council on Bioethics. *Source*: Photograph by Catherine Calvert and Isabella van Rel.

come to some kind of agreement. Another reason that I focus on this working party is because my involvement in it was influential on my own thinking. The themes and conclusions of the resulting report, *Emerging Biotechnologies: Technology, Choice and the Public Good* (hereafter *Emerging Biotechnologies*) diverged from those normally found in bioethics reports and contributed to my attempts to develop an approach to normativity that is consistent with STS, which I expand on in the second half of the chapter.

It is significant that the focus of the report was "emerging biotechnologies," not synthetic biology. The report was written at a time when it seemed that reports on synthetic biology were being published with great regularity—there were approximately 40 English-language reports between 2004 and 2011 (see Wiek et al. 2012). Rather than writing a specific report on each new technology as it rose to prominence, the Nuffield Council wanted to be able to say something that could apply more broadly to "emerging biotechnologies," including regenerative medicine, genetic engineering, personalized medicine, bionanotechnology, and synthetic biology (Nuffield 2012, xviii).

The working party was initially, and perhaps unsurprisingly, tasked with writing a report on "the social, ethical, and legal implications that are raised by new and emerging biotechnologies." However, in one of our earliest meetings, several of us objected that this was based on some problematic assumptions (similar to those discussed above): that the "implications" come after the technology and that there was a certain delimited range of things we should be concerned about (namely, "social, ethical, and legal"). Some of us pointed out that a key feature of emerging technologies was that their future trajectories were uncertain, making it very difficult to read off their "implications."

So, we did not do what we were initially tasked to do. Instead, we focused on three characteristics that we determined "emerging biotechnologies" possessed: uncertainty, ambiguity, and transformative potential. These three characteristics are unpacked in the *Emerging Biotechnologies* report, so I will not elaborate on them here. The point I want to emphasize is that the report took the distinctive features of emerging technologies seriously. For me, uncertainty was the feature that was most important because, as the report argues, "under conditions of uncertainty, emphasis shifts from the attempt to select the optimum pathway for biotechnology to fostering diversity of technological development" (Nuffield 2012, xix). I will return to the importance of fostering diversity below.

The report argues that because of their distinctive features, emerging biotechnologies are particularly susceptible to being framed in certain ways, which are often narrowly economic. This argument draws on the "Collingridge dilemma" (Collingridge 1980)—a key tenet of technology studies—which shows that in the early stages of the development of a technology, when it is emerging and its trajectory is uncertain, the power to influence its development is high, and it can be prematurely locked into certain paths and excluded from others.[2] The report maintains that emerging technologies are pushed in directions that prioritize commercial over other outcomes, such as the public good. In fact, economic framings are so engrained in our thinking about scientific and technological developments that their dominance is often not even recognized. In these situations, "alternatives are deleted not by argument or by force, but by the circumscribing of imagination itself" (Nuffield 2012, 66). Of the whole report, it is this sentence that most resonates with me and with my experiences in synthetic biology. I see imagination being circumscribed at every turn. My interpretation of what the report advocates is—to put it grandly—the emancipation of imagination.

In developing these ideas in the working party, we had started to deviate from the path a bioethics report usually takes. Typically, such reports enumerate the ethical "issues" raised by the particular technology under focus, which is what we were originally expected to do. In synthetic biology, for example, there is a familiar list of issues that are regularly raised in the discussion of the field (e.g., biosafety, biosecurity, and the creation of life). In the Nuffield report, we stretched what counts as ethical, as is indicated by the report's subtitle "technology, choice and the public good." We wanted to make the point that upstream choices about government investment in scientific and technological fields—choices that may seem to be the concern of science policy—are actually ethical choices. This refocuses attention on what is considered to be a topic of ethical discussion in synthetic biology and who gets to decide.

Although our approach was somewhat unconventional, we were forced to be more so because we were told by our secretariat that all Nuffield reports had to have an "ethical framework" and that we should identify one that we could apply to emerging biotechnologies.[3] Such a framework was meant to facilitate the consideration of novel emerging biotechnologies in the future. I found the idea of taking an abstract ethical framework "off the shelf" and applying it to a case study very problematic. I was concerned that such a framework would lead to generalizations about science and engineering that would not recognize their contextual and historical specificity. This is a familiar criticism of bioethics, and others have pointed to the tension between certain universal conceptualizations of ethics and the attention to particularity and contingency we find in the social sciences and humanities (Heeney 2017). This tension is particularly significant in STS because such attention to contingency is a defining feature of STS research. Steve Woolgar and colleagues (2009, 22), for example, maintain that one of the key sensitivities of STS is "an emphasis on the local, specific and contingent in relation to the genesis and use of science and technology." And Michael Lynch and Simon Cole (2005, 297) argue that STS "expertise" resides in its "deep familiarity with the substantive topic of inquiry" rather than in the formulation of general principles. Channeling these STS proclivities, I asked the rest of the working party why, if we were emphasizing the context-specific framing of emerging technologies by identifying their distinctive features, we were attempting to impose a set of principles that could be applied across all contexts.

After much discussion, the framework we eventually adopted was grounded in the "communitarian turn" in bioethics and guided by the values of equity, solidarity, and sustainability. The communitarian turn marks a shift away from concerns with individual freedoms and harms that are more typical of bioethics and toward collective interests and the public good (Nuffield 2012, 62). It is perhaps not surprising that as a social scientist, I was happy with this move. But the key point I want to draw out here is not that we shifted from the individual to collective. It is that we took this a step further to argue that normativity comes about through interaction with others. The report puts this elegantly when it maintains that "an ethical basis for action is not one that can be found by a single thinker reasoning in isolation but one that is to be established instead through a discursive engagement between differing perspectives" (Nuffield 2012, 62). This resonates strongly with the idea of an emergent form of critique described in chapter 5. Normativity in the Nuffield report is not something that is the result of introspection, nor is it imposed from on high; instead, it requires ongoing negotiation and discussion with others, who might include stakeholders and publics.

Some may say that this extends ethics into the realm of politics, and I would tend to agree. This, again, makes the report less like a typical bioethical report. The broadening of the ethical to encompass the political is advocated by some STS researchers, often as part of an argument for the democratization of science and technology. For example, Jasanoff (2005,

191) talks favorably of attempts in the UK to "resist the professionalization of this discourse and to reestablish ethical deliberation as a field of democratic engagement, accessible to ordinary people as well as experts." She also shows how in some national contexts, civil society groups have successfully used bioethics as a tool of diversification, as a way to introduce new voices and new issues. We made a similar point in the *Emerging Biotechnologies* report, maintaining that "engagement beyond traditional scientific elites can act as a counterbalance to technical interests and cultures" (Nuffield 2012, xxi).

As a consequence, from the drawing room in the elegant Georgian building where we held our closed discussions, we presented the bioethics building as a venue that could facilitate "engagement beyond traditional scientific elites." We did this by morphing and stretching the ethical, pushing it into the domain of the political. We were not only challenging the bioethics framing; in a sense, we were attempting to bring down the walls of the very building in which we were comfortably seated.

DEVELOPING A NORMATIVE ORIENTATION

As noted above, my involvement in this report was influential on my own thinking and my attempts to articulate a normative orientation for my own work, one that is authentic to and consistent with the sensibilities of STS. This articulation will be my focus for the rest of the chapter. It is significant that, in recent years, a number of other STS researchers have aimed to be more explicit about their ethical orientation. Two influential examples are Jenny Reardon (2013) on justice and Barbara Prainsack (2018) on solidarity. In the context of synthetic biology, Rabinow and Bennett (2012, 43) argue for a virtue ethics based around the Aristotelian idea of flourishing, which involves "the care of others, the world, things, and ourselves." I see all of these as responses to the normative demands that are increasingly placed on social scientists who engage with science and technology.

Before putting forward my arguments for a particular normative orientation, it is necessary to address the notion of normativity itself. As the philosopher Hans Radder (2009, 893) puts it, "Although the term normativity is often used in scholarly literature, its meaning is not very clear." Normativity is something that is often discussed but less often interrogated. According to the *Oxford English Dictionary*, something is normative if it implies or is derived from a norm, and a norm can be defined as a "directive concerning what people should (or should not) say or do" (Radder 2009, 893). In the context of ethics, Nathan Jun (2011, 94) argues that norms have a "universal and abstract character."

This emphasis on prescribing what people ought to do in a universal and abstract sense does not sit easily with the specific and contingent findings of STS. It implies there is one correct path that can be identified, independent of context. This is the kind of normativity that I feel is often expected of me by scientists and research funders. Although it may bear little resemblance to much bioethics in practice, it is the type of normativity I object to when I ask not to be described as a bioethicist.

Because of my dissatisfaction with this "strong" form of normativity, I have found it necessary to attempt to elaborate an alternative. This alternative grew out of my experiences in synthetic biology and my involvement with the Nuffield report, and I find it valuable in orienting my own activities in the field. It builds on the STS insight that "things could be otherwise."[4] This form of normativity rests on the point that, at its core, STS involves a close study of scientific knowledge and practices, which involves learning as much as one can about the field of study. This results in a sensitivity to the contingency of knowledge claims and to the assumptions that frame them. The recognition that science and technology do not have to be the way they are is dependent on this sensitivity because, to paraphrase Brian Wynne (1993), once we identify the contingency of our commitments, we render them open to change.

I am proposing this position, which I am calling "otherwising," as a guiding normative principle for STS. It is one that is grounded in the STS literature. For example, Jasanoff (2016, 236) identifies it when she describes "that first baby step into STS, the radical, critical move that asks, 'Why is it so, and must it be?'" Woolgar has on many occasions used the formulation "it could be otherwise" and describes it as a "well-established form of revelation" in STS (Woolgar and Lezaun 2013, 326). And Latour (2005, 89) captures it when he refers to "the troubling and exhilarating feeling that things *could be different*" (emphasis in original). I also find it in Andrew Stirling's (2008, 279) notion of "opening up," which involves recognizing the plural and situated nature of knowledge claims to reveal "inherent indeterminacies, contingencies, or capacities for agency." This can allow new questions to be asked and alternative technological pathways to be explored.

By proposing otherwising as a guiding principle in this way, I am aware I am in danger of advocating a contradictory "transcendent-but-located virtue"

(Stirling 2016). The potential problem here is: How is it possible, from a position that rejects the universal character of normativity, to propose something that applies across all times and all places? I would argue that otherwising does not fall into this trap, however, because it is a strategy, an approach, rather than an external authoritative standard. It is nondirective, and the direction it takes will be dependent on the specificities of the context.

Some might find this nondirectiveness problematic, and this is an issue I return to below. For now, I just want to emphasize that showing that things can be different demonstrates that they can be changed; it challenges "the circumscribing of imagination itself" (Nuffield 2012, 66). This is potentially emancipatory because it opens up the possibility for other directions to be taken. It could be argued that since it is nondirective, this position should not be thought of as normative, and although I have provisionally put it under this heading, a point that I return to below is that we can think of otherwising as belonging in the realm of the subjunctive—the possible, the "could"—rather than the normative, roughly glossed as the "should."

I have identified otherwising in the STS literature, but if it is understood in terms of revealing possibility and potential, it can be found across the social sciences and humanities more broadly. For example, I am not a historian, but what I appreciate about the history of science is the way in which it demonstrates the plurality and multiplicity of the past, showing that things could have been different and thus freeing us to consider alternative versions of the present and the future. Georges Canguilhem (2008, 28) says that "the benefit of a history of science properly understood is to reveal the history in science—by which we mean the sense of possibility." Along similar lines, Charles Sanders Peirce (1998, 114) argues that "one of the main purposes of studying history ought to be to free us from the tyranny of our preconceived notions." A study of the past can help reveal our current framings.

Anthropology, in its investigation of other cultures, also shows the incredible diversity of ways of organizing human life, leading anthropologists such as Carrithers (2005, 433) to argue that "an understanding through possibilities goes to the heart of anthropology." He goes on to say that a consequence of this recognition of diversity is a reinterpretation of one's own culture, since "it becomes apparent that one's own arrangements are 'never the only way possible'" (Carrithers 2005, 435). Martin Holbraad and colleagues (2014) similarly maintain that the value of anthropological research is that it elicits the "manifold of potentials for *how things could be*" (italics in original).

I also find the idea of otherwising in Isabelle Stengers's work, which, as I understand it, is about cultivating a sense of the possible, to allow new narratives about the future to be generated. For example, she says, "I consider that my job, as a philosopher, is to activate the possible, and not to describe the probable" (Stengers 2011, 1). Mariam Fraser (2006, 66) argues that Stengers's position is one where "the emphasis on *could* suggests that ethics is ultimately about the creation of novel relations—not *because* they are novel, but because the attempt to do this is, precisely, about tugging at unrealized potentiality" (emphasis in original). This idea of "tugging at unrealized potentiality" is central to otherwising.

Although this approach is not explicitly directional, I do think there is a politics to it. I find otherwising in the work of Donna Haraway and other feminist STS scholars such as Natasha Myers (2015). For example, in her discussion of situated knowledges, Haraway (1988, 590) says, "We seek those ruled by partial sight and limited voice—not partiality for its own sake but, rather, for the sake of the connections and *unexpected openings* situated knowledges make possible" (emphasis added). The foregrounding of such unexpected openings reveals dominant discourses and brings alternatives to light. This demonstrates that otherwising requires others, those who think differently and who can reveal previously unseen potential. In fact, Alan Irwin (2015, 30), using the phrase "the future could be otherwise," argues that "conveying this sense of possibility has to be a core purpose of public engagement." This connects directly to the point made in the Nuffield report that normativity comes about through interaction with others, that it requires "a discursive engagement between differing perspectives" (Nuffield 2012, 62). The STS researcher cannot do otherwising alone since it relies on interactions that cultivate "an active lucidity about the partial character of one's own questions" (Stengers 2011, 12) on the part of all of those involved.

This connects again to the necessity to pay attention to the specificities of the particular empirical context. Being embedded in such a context provides opportunities for interactions with relevant others who have different views and perspectives. What results from these interactions will often be unexpected. An example of this is the "wedge in the door"—the guiding metaphor and normative orientation developed in the Synthetic Aesthetics project and discussed in chapter 5. This metaphor only arose because of the particular interdisciplinary interactions in the art studio between synthetic biologists, social scientists, artists, and designers.

Does otherwising, then, give STS researchers all they need to respond to the pressures imposed on them to be normative? As noted above, otherwising could be argued to belong in the realm of the subjunctive—the "could"—rather than the "should." It is a strategy and approach, but it is not directional because it does not assume the STS researcher has superior grounds on which to tell others what they ought to do. But is "could" really strong enough? Some would say it is not. Stilgoe and Guston (2017, 870) maintain that "an STS or a responsible innovation that serves only to expose technocratic framings but not to construct new, more expansive, diverse, and participatory ones is, in our view, not going far enough." Hasok Chang (2012, 268), a historian and philosopher of science, would concur. The position he advocates is epistemic pluralism, which in its recognition of the value of diversity has clear resonances with otherwising. But he calls his position "*active normative* epistemic pluralism" (emphasis added) because it involves actively seeking alternatives and cultivating multiple systems of scientific knowledge. Chang says his position "is not an idle pronouncement to 'let a hundred flowers bloom', but the effort of actively cultivating the other 99 flowers" (260).

Although I am sympathetic to such arguments, in my experience, the extent to which alternatives can be actively cultivated is always context-dependent—it will depend on the room one is in. Although there is great potential for this in the art studio, for example, opportunities may be more limited in other spaces. In retrospect, the arguments I made about the potentially negative consequences of the commercialization and mainstreaming of synthetic biology at the SB7.0 conference in Singapore (described in chapter 2) were an attempt to engage in otherwising, albeit one that was limited by the confines of that particular room. The power of simply showing contingency where necessity is assumed should not be underestimated, however. In some contexts, this is in itself a radical and challenging move. It is only once we are aware that things could be different that we can start to ask how they should be changed.

THE BIOETHICS BUILDING AS A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

In attempting to articulate a form of normativity that incorporates the sensibilities of STS, I may appear to have strayed rather far from the bioethics building. But my attempt to develop otherwising was itself a response to spending time in that room—a response to pressures to be normative under the heading of ELSI and to the difficulties I encountered when the scientists and engineers I interacted with assumed that I was a bioethicist.

My formulation of otherwising owes a great deal to my experiences on the Nuffield Council on Bioethics working party. It draws on the substantive arguments we developed in the *Emerging Biotechnologies* report—that it is necessary to challenge the narrowly economic way in which emerging biotechnologies are often framed and to recognize that normativity requires interaction with others. Moreover, the interdisciplinary environment of the working party allowed us to explore the ways in which bioethics itself could be otherwise. We extended the realm of the ethical to incorporate questions of research funding and policy choice, and we challenged the distinctive expertise of bioethics by arguing for the incorporation of diverse voices.

It is significant that both the Nuffield Council and Hastings Center allowed for this type of challenge. This was facilitated by the institutional independence and inclusivity of both spaces, reflected by the disciplinary diversity of the members of the working parties in both buildings. This diversity has been a feature of both institutions from their beginnings (Callahan 2012; Franklin 2019), and it is, according to some commentators, a feature of bioethics itself. Nicky Priaulx (2013, 9), for example, maintains that although "bioethics provides a home capable of accommodating a wide range of disciplinary actors, methods and problems, it is also true to say that the 'bioethical residents' (if they really are that) do not always happily co-exist or share a unified understanding about what the bioethical project entails." Others see bioethics as best understood as a heterogeneous space that allows a range of different people to contribute to the discussion.[5] I will tentatively conclude that the bioethics building is a good space to spend time in as an STS researcher, albeit with some caveats.

These caveats concern the dangers of detachment and a division of labor. Since the buildings that I have discussed here are physically detached from broader institutional contexts, they are separated from ongoing scientific research practices. This means there is a risk of evaluating these practices from a distance and putting forward decontextualized generalizations—the kind of generalizations I resisted when objecting to the imposition of an ethical "framework" in the Nuffield report. This is closely connected to another tendency often associated with bioethics, which is for the "ethical" and "scientific" issues to be neatly separated with responsibility for them allocated to different disciplinary groups. This is an ongoing danger in the bioethics building and one that has to be continually resisted, particularly because this division of labor is comfortable and often ends up supporting the status quo. One way of resisting this is to refuse the separation of the epistemic and normative and to challenge a priori statements about what is or is not an ethical "issue," paying attention instead to what arises out of the particular empirical context.

This compels me to return to a tension that appears in many of the chapters of this book. Although I have argued in this chapter for embedded, informed empirical work, out of which otherwising can emerge, a problem with such embedded research is that the STS researcher can get too close to a field, which can lead to domestication or complicity, as I experienced to varying degrees in all the rooms discussed in the previous chapters. Although there is a danger of work in the bioethics building becoming overly detached from the scientific research, it is also clear that some level of detachment can be advantageous. It helps demonstrate that there is a place for work on synthetic biology that does not involve collaboration with scientists and engineers and does not try to intervene from within the field. This type of work does not have to surrender critical distance because it comments from outside. This arguably provides the opportunity for a less compromised and domesticated form of critique.

7 THE POLICY ROOM

The policy room is where one can experience the headiness of exposure to power, exhibited by sharp suits, big budgets, a sense of urgency, and proximity to media attention. Entering this room provides distinctive opportunities for interventionist work. As I became more involved in synthetic biology, I also became more involved in policy initiatives. To guide my activities in this space, I turned to science and technology studies literature that has engaged with policy, as well as research from the closely related fields of science policy and innovation studies. In this chapter, I show how I attempted to use this work to challenge narrow framings of innovation and encourage institutional reflexivity—to show that things could be otherwise in the policy room.

I focus on my involvement in two policy groups. The first is the Bioscience and Society Strategy Advisory Panel for the UK's Biotechnology and Biological Sciences Research Council. I was on this multistakeholder panel for eight years. The panel was itinerant, meeting in hired executive-style spaces in central London. My role in this group became one of attempting to introduce an openness to broader perspectives in the context of institutional changes and political pressures. The second is the UK Synthetic Biology Roadmap Coordination Group, a ministerially appointed committee tasked with producing a report on a tight timescale that led to the release of over a hundred million pounds of funding for synthetic biology in the UK. The group was made up of representatives from business, academia, and government. We met every two weeks for four months in a glass-walled meeting room in the UK's Department for Business, Innovation and Skills in Westminster. With an

STS colleague, I repeatedly tried and arguably failed to integrate STS insights into the discussion and the final report.

While I was on the Synthetic Biology Roadmap Coordination Group, the notion of responsible research and innovation (RRI) started rising in prominence in science policy circles, and I was partially responsible for introducing the term to the group. The word "responsible" might, at first glance, seem the most important in the phrase "responsible research and innovation" because it suggests the injection of missing normativity into scientific research. But I argue that it is the word "innovation" that is the most generative in the policy room because RRI can encourage a critical analysis of innovation itself.

Although one can observe and collaborate in the policy room, I entered it primarily to intervene, so the notion of intervention is central to this chapter. I end it by reflecting on the capacity for intervention in the policy room and asking whether this makes the policy room the most significant of all the rooms discussed in this book.

POLICY ENGAGEMENT IN SCIENCE AND TECHNOLOGY STUDIES

The policy room has considerable appeal because of the possibilities it provides to make "critical, transformative interventions within technoscientific worlds" (Suchman 2014), to return to a quotation from the introductory chapter. Some argue that policy work is a natural extension of the academic strand of STS—that it takes the field's "reflexive tradition of analysis into very difficult and even more intensely power-laden policy domains" (Kattirtzi and Stirling 2018, 388). But becoming closely involved in policy can lead to criticism from one's more academically oriented colleagues. As Stirling puts it, "I am not regarded as a proper STS person by some in the field—perhaps because of my direct engagement with policy" (Kattirtzi and Stirling 2018, 387–388). He adds that he sometimes finds his work "frowned upon because external engagement sullies internal identity" (393). This is a danger of the policy room, but it is one some STS researchers are willing to risk because of the potential for intervention.

Webster provides a useful account of STS in policy in an article subtitled "Social science in the policy room."[1] His aim is "to illustrate, through drawing on my experience as a researcher in STS, some of the difficulties involved in crossing this boundary, in adopting what Lynch and Cole (2005, 269) call 'the normative turn,' in opening doors and occupying strange policy lands" (Webster 2007, 462). The "normative turn" is a phrase used to describe "research that *intervenes* in public controversies about science and technology" (Lynch and Cole 2005, 269, emphasis in original). It marks the fact that in the last decade, STS has been increasingly paying "urgent attention to issues of public participation, power, democracy, governance" (Hackett et al. 2008, 3).

Webster explains why STS researchers are gaining entry to policy rooms. The story is one that is familiar from previous chapters: The state and its agencies want science to be more "accepted and acceptable," and "the expertise of STS is seen by government as the midwife through which the reproduction and delivery of science can be secured in a more 'socially responsive and responsible' way" (Webster 2007, 462). We should accept these invitations to enter the policy room with some trepidation, however. Webster warns that "in responding to these demands . . . STS needs to retain its reflexive and critical edge" and to anticipate "cooption and capture" (Webster 2007, 462).

Webster's article gives examples of his own involvement in policy rooms, and these examples demonstrate the kinds of work STS researchers can do in these spaces and the skills they can bring. Not surprisingly, given the attention to specificity and contingency in STS, Webster does not explicitly identify or recommend a normative orientation that an STS researcher should adopt in the policy room. As in the bioethics building, however, I found myself searching for such an orientation in this place. And on reflection, I do see my responses and suggestions in the meetings as consistent with the idea of otherwising explored in chapter 6.

The lines between the bioethics building and the policy room are blurred, of course. In the Nuffield Council on Bioethics working party, we extended our remit beyond the ethical as narrowly conceived to address questions of research funding and policy choice—topics of central concern in the policy room. But the policy room has its own distinctive features. Its connections to power and funding are more direct, and the room is often infused with a sense of urgency because policymakers continually have to deal with external demands and constraints. Another feature is that this space is the most formal of all of the rooms discussed in this book, both in terms of behavior and dress code. All of this gives a sense of importance to the activities that take place within it. The first policy room I entered is the one I turn to now: the Biotechnology and Biological Sciences Research Council's (BBSRC) Bioscience for Society Strategy Advisory Panel.

BIOSCIENCE FOR SOCIETY AT THE BBSRC

The BBSRC, created in 1994, is the largest public funder of the nonmedical biosciences in the UK. It also has a responsibility to "provide advice, disseminate knowledge, and promote public understanding in the field of biotechnology and the biological sciences."[2] From 2004 to 2019, the BBSRC had seven strategy advisory panels of which the Bioscience for Society Strategy Advisory Panel (BSS) was one.[3] I attended my first BSS meeting in January 2011, and I was on this panel until December 2019. BSS had a mixed membership of approximately ten people, which changed over the years and included sociologists, ethicists, biologists, and experts in animal welfare, journalism, and museum curation, as well as representatives from industry and nongovernmental organizations (NGOs). The secretariat consisted of four BBSRC officials who attended all the meetings. The remit of BSS was to provide "strategic input on the social dimensions of the conduct and outcomes of research supported by BBSRC."[4]

BSS was established in 2004, in the wake of the 2003 "GM nation?" public debate into the commercialization of genetically modified (GM) crops in the UK.[5] It was meant to "inform BBSRC of public attitudes and interests relevant to the conduct and outcomes of bioscience research" (BBSRC 2004, 20), replacing the Advisory Group on BBSRC Response to Public Concerns (28). As can be seen, concerns about public concerns were paramount in the panel's formation.

The journal *Nature* published a commentary that celebrated the formation of the panel and highlighted its emphasis on public attitudes to science:

> In many European nations, there is little call for upstream engagement. But Britain, where a lack of public trust in science is perceived as a serious problem, is a notable exception. Not all of the country's funding bodies have taken this on board. The Biotechnology and Biological Sciences Research Council, which is setting up a permanent committee of non-scientists to advise on strategy, leads the way. (Nature 2004, 883)

As mentioned in previous chapters, public engagement is not my specialist area, but being an interested social scientist involved in the early days of synthetic biology in the UK was enough for a BBSRC official to suggest I apply to join the panel. He assured me that expertise in public engagement was not a requirement.

The panel met three times a year, always in central London but not always in the same place. I discovered several years into my appointment that this was because government committee requirements dictated that if the panel always met in the same place, it would become a "regular place of work," which would have tax implications. So, our itinerancy was enforced. The rooms often hired for our meetings were in two distinctive buildings: the Royal Institute of British Architects (RIBA) headquarters, an elegant 1930s art deco building on Portland Place, and One Kemble Street, a 1960s brutalist cylindrical tower block in which each room provided an impressive panorama of the London skyline. Our half-day meetings were usually catered with unexceptional sandwiches and plentiful supplies of tea.

The papers for the first meeting I attended explained that the panel should act as a "critical friend" to the BBSRC. The panel's remit was to identify "issues of public salience and emerging topics relating to societal issues in the biosciences," to provide "oversight of appropriate opportunities and approaches for engaging with significant stakeholders," and to advise the BBSRC on "integration of the consideration of ethical and other social issues when planning policy and funding."[6] Although there is a separation of the "social and ethical" from the "scientific" in this description, it did not seem to be worth quibbling with this framing given that the panel itself represented laudable efforts to ensure a place for diverse expertise in the BBSRC's official structures.

To give a feel for this particular policy room, I will give a snapshot of some of the work we did over the years I was on the panel. Our roundtable meetings always began with horizon scanning, where we identified topics that we considered salient for the BBSRC. We then turned to issues we were tasked with investigating. For example, we produced a short report on "naturalness" for the BBSRC's website[7] and suggested changes to the obligatory "ethics" section of BBSRC research proposals, attempting to make it more than a box-ticking exercise. We were also involved, to some extent, in the BBSRC's high-level strategy development. For example, we monitored the activities of the other strategy panels and commented—often critically—on drafts of the BBSRC's strategic plans. We tried to get a broader range of voices heard at the level of priority-setting and funding decisions, and we were influential in the decision to appoint a social scientist to the BBSRC council (the highest layer of the organization) for a four-year term.[8]

As I had anticipated, and as was to be expected perhaps, given the rationale for the formation of the panel, much of our work revolved around public engagement. During my time on the panel, we advised the BBSRC on public engagement exercises on bioenergy and global food security, we discussed do-it-yourself biology and citizen science, and we were also responsible for assessing the public engagement activities of the BBSRC's eight research institutes, which receive approximately 25 percent of the BBSRC's total funding.[9]

I found myself continually asking why public engagement was being required or considered by the BBSRC in these various different contexts. In some cases, an instrumental rationale was implicit or explicit—it was hoped that public engagement would increase legitimacy for the BBSRC's activities. In other cases, a more substantive motivation seemed to be at work; the organization wanted to take broader social considerations into account to make better-informed funding decisions. My own answer to the "why public engagement?" question developed over the years that I was on the panel. I came to the conclusion (as noted in chapter 6) that in order to challenge the assumptions that were being made and the ways in which issues were framed, it was necessary to bring in people who saw the world differently (Felt 2014). This could, but did not necessarily have to, involve publics.

Much of the panel's work involved trying to shift the understanding of public engagement in the BBSRC (and in the research it funded) from one-way, deficit-model-style dissemination and communication of the science to two-way dialogue.[10] This was an ongoing battle, and the one-way framing of public engagement (which often involved enthusing schoolchildren) was consistently prominent in descriptions of and plans for public engagement over the eight years I was on the panel. Some other members of the group and I tried to tackle this by challenging the idea that there was one "public" that could be treated as an undifferentiated group. We suggested that stakeholders with relevant expertise and academics from disciplines outside the biosciences—including social scientists, humanities scholars, regulators, artists, and citizen scientists—could be productively engaged in the BBSRC's work.[11]

Reflecting on the purpose of the panel more broadly, a subgroup of us increasingly came to the view that the role of BSS was to facilitate culture change within the BBSRC—to help it become a more reflexive organization. This idea was adopted by the secretariat, and in one of our meetings, I was secretly thrilled when we were explicitly tasked with "developing advice on other ways, beyond public engagement, that BBSRC could develop its reflexivity."[12] This seemed to be a clear case of STS ideas infiltrating the policy room, although it raised questions about what was meant by reflexivity in this context and how it could be operationalized. In a well-known paper, Wynne (1993, 322) argues that institutions are reflexive when they identify and critically examine their "taken-for-granted models of society, and of science and its boundaries embedded within their culture." This type of critical reflection often follows from being exposed to unfamiliar views. Along these lines, the BBSRC secretariat usefully interpreted reflexivity as the "consideration of wider perspectives,"[13] which they later elaborated as "opening-up thinking to non-bioscience disciplines and wider perspectives wherever they might be found."[14] This was a framing that helped challenge the narrow deficit-model interpretation of public engagement.

As these snapshots indicate, this was in some ways a conducive policy room. At the best of times, I felt that the panel was acting effectively as a "critical friend" to the BBSRC: that our contributions were taken on board by a secretariat that had a good understanding of the issues and was committed to transmitting them to the higher echelons of the BBSRC, where they could potentially shape research funding and organizational strategy. In my notes on one of the meetings, I wrote, "This is where I have an influence on science."

But being on the panel could be frustrating at times. Reading through my 98 pages of notes on the meetings, the repetitions are striking. Several of us kept making the same points and confronting the same obstacles, particularly around the instrumental approach to public engagement outlined above. These difficulties were partially structural. The panel was under the remit of the BBSRC's External Relations Unit, which was also responsible for corporate communications and promoting the BBSRC's work—activities that did not sit easily with the objectives of challenging assumptions and encouraging reflexivity. At a higher level, there were also constraints that came from being on a group that was part of an organization whose overall mission was to support the biosciences. Giving greater emphasis to non-bioscience approaches—even those of closely related disciplines such as environmental sciences—was not consistent with the BBSRC's agenda.

Another important concern was that the very existence of BSS gave the rest of the organization an excuse for not engaging with the "social" dimensions of their activities because these could simply be delegated to this dedicated panel. This meant that the BSS could sit comfortably within the structures of the BBSRC without challenging business as usual—in other words, that BSS was a sop. Toward the end of my time on the panel, these concerns were more regularly voiced, by the secretariat as well as the panel members, reflecting an increasingly volatile political climate in which the institution was having to negotiate radical internal restructuring,[15] voluntary redundancies, and the uncertainties of the approach of Brexit.

This ties back to the point made above about the importance of external pressures in policy rooms. That the BBSRC was subject to such pressures was particularly apparent in its unquestioned focus on wealth creation and in the presence of industry representatives on all its panels, including BSS. Importantly, the BBSRC was (and is) completely dependent on funding from the Treasury, so its survival required its alignment with the political priorities of the time.

These constraints are, to some extent, constitutive of the policy room. I remained on the Bioscience for Society Strategy Advisory Panel for as long as I did because, on balance, I thought the work we did had value and that we did make a difference, even if this difference was difficult to evaluate. But by early 2019, institutional restructuring led to a hiatus in meetings, and at the end of that year the panel was disbanded. The reason we were given was that the BBSRC had decided that "societal perspectives" were better embedded across all the BBSRC's panels rather than delegated to a separate entity. At the time of writing, it is not clear how this will be achieved.

THE UK SYNTHETIC BIOLOGY ROADMAP

In stark contrast to my eight-year term on BSS, I was only a member of the Synthetic Biology Roadmap Coordination Group (SBRCG) for four months—showing the temporal variability of the policy room. The SBRCG had a specific task: to produce a synthetic biology roadmap for the UK on a timescale that was constrained by the government's financial calendar.

A driving force behind the roadmap was the personal interest of the then Minister for Universities and Science David Willetts (the same minister who spoke at the SB6.0 conference, described in chapter 2). Willetts went to his first synthetic biology meeting in London in April 2011 and came back "absolutely enthused with the potential and possibilities demonstrated by synthetic biology" (Uffindel 2012). Soon after, he appointed a committee of "leading researchers and business experts in a group chaired by Dr. Lionel

Clarke of Shell to produce a synthetic biology roadmap to set out the time-frame and actions to establish a world leading synthetic biology industry in the UK" (Willetts 2012a). The group held its first meeting in November 2011.

I was aware of these developments, but I was not invited to join the group until three months later, in February 2012. I received an email from the chair saying that it had become apparent that there were key specialist areas unrepresented within the group. I agreed to join with Claire Marris, an STS researcher then based at King's College London who was working closely with synthetic biologists at Imperial College London. The group we joined comprised synthetic biology researchers and representatives of industry, government, and the research councils. Claire and I have written about our experiences on the SBRCG in a jointly authored paper (Marris and Calvert 2020), so I will not describe them in detail here. Instead, I extract the features of this experience that are pertinent to considering the policy room as a space for STS. I also discuss the reactions to the publication of our paper.

A notable feature of our involvement in the SBRCG is that we joined the group when it had already been running for three months (with meetings held approximately every two weeks). The ideas that had formed and coalesced in this room proved incredibly difficult to challenge, showing that *when* you enter a policy room is important. Being brought in late, as an afterthought, is often a feature of social scientific involvement in synthetic biology in research grants as well as in policy contexts, limiting the influence it is possible to have on framings and guiding assumptions.

The group normally met in a modern, glass-walled meeting room in an office building a stone's throw from Westminster Abbey, in what was then the UK's Department for Business, Innovation and Skills (see figure 7.1).[16] Those of us who were not government employees were not permitted to enter these particular corridors of power unaccompanied, so we waited for an escort in the large reception area adorned with "Britain is great"[17] posters and a wall of TV screens projecting huge images of the faces of senior government officials, including Willetts.

Once in the room, Claire and I became aware of the framings and guiding assumptions already present. These were that synthetic biology should be funded because it would lead to economic progress and that public reticence about the field could potentially block that progress, meaning that public acceptability was a key problem to be addressed. Again, paramount in this policy room were concerns about public concerns, something

FIGURE 7.1
The UK's Department for Business, Innovation and Skills. *Source*: Photograph by Steph Gray.

Marris (2015) calls "synbiophobia-phobia." In addition, the narrow economic framing meant that alternative visions for synthetic biology, such as the BioBricks Foundation's call for the field to "benefit all people and the planet" (see chapter 2), could not even be considered.

Claire and I were tasked to write a section of the roadmap. The title we were initially given was "Acceptability." Keen to move the onus away from public acceptance of the technology and toward the purposes and motivations driving the research, we suggested an alternative title: "Responsible Research and Innovation." This was a term that was rising in prominence in the science policy discourse at the time, although there were few papers published on the topic. There had been a "Franco-British Workshop on Responsible Innovation" in London in May 2011, which some members of the SBRCG attended, so they were aware of the concept and happy with the title change.

Drawing on the STS literature, in our section of the text we wrote that it was important that debates on emerging technologies "go beyond the community of experts to open up discussions about the purpose of innovation"

(SBRCG 2012, 19). To counter deficit-model framings, we emphasized that "'the public' is not a singular pre-existing mass that accepts or rejects particular technologies" and that public acceptance "cannot be adequately dealt with through communication aimed at reassuring the public" (19). Instead, we made the point that "'engagement' means genuinely giving power to a wide range of diverse social groups . . . taking their concerns seriously, and enabling them to participate throughout the whole pathway of technological development" (21). Finally, we made the point that integrating social sciences, humanities, and arts researchers into synthetic biology could help foster responsible research and innovation.

Because of the pressure on the SBRCG to produce the roadmap in a short time, there was no opportunity for most of the members of the group, including Claire and me, to see the proofs before the document was published. On reading the final report, we were relieved that all of our text quoted above appeared in the final version, but disappointed to find that the roadmap overall reinforced the framings that were dominant when we first joined the group. For example, the insertion of a "public acceptability" subheading in our text made it look as if we were arguing that public acceptability was the key obstacle in the path of the economic development of synthetic biology. And of the five recommendations made in the roadmap, the notion of responsibility only appears in one of them: "Invest to accelerate technology responsibly to market" (SBRCG 2012, 32). As the two lead authors of the roadmap later wrote, "This recommendation directly associates the notion of responsibility with the acceleration of technology" (Clarke and Kitney 2016, 250), an association we found deeply problematic. These authors go on to celebrate what they see as the achievements of the roadmap in respect to RRI:

> Social awareness alongside technological expertise is now embedded in training programs, through the framework of Responsible Research and Innovation (RRI) as recommended in the 2012 Roadmap. Outreach and community engagement are important and integral to the UK synthetic biology activities at all the research centres, and effective consideration of RRI has become an essential feature of research funding. (Clarke and Kitney 2016, 251)

It is the case that RRI became central to synthetic biology research funding following the publication of the roadmap, a topic to which I return below. But there is a gulf between "outreach and community engagement," which implies one-way dissemination of knowledge to passive recipients, and opening up discussions about the purpose of innovation to a broad range of stakeholders, which we had argued for in the roadmap.

Overall, we felt that despite being given the opportunity to contribute to a significant policy document, our contributions had been misrepresented—albeit most likely unintentionally—in the rest of the document and in the way it was presented after its publication. This led us to reflect on the constraints of this particular policy room. One of the most significant, as noted above, is that we entered the room late. This was particularly problematic given the short amount of time in which the report had to be written and published. Another constraint was the nature of the task itself. We were involved in writing a technology roadmap, and unlike a real roadmap that one might use to navigate an unfamiliar city, this roadmap only laid out one path—one hoped-for trajectory for this particular technology. There was no place for alternatives, for diversity, plurality, or otherwising.

The publication of the roadmap was a notable marker for synthetic biology in the UK. It resulted in the release of £126 million of funding announced at the SB6.0 conference in London in 2013. This included funding for six synthetic biology research centers, all of which required responsible innovation and one of which was awarded to the University of Edinburgh, benefiting me directly. It also resulted in the formation of the Synthetic Biology Leadership Council, mentioned in chapter 5, which was tasked with paying special attention to RRI (Willetts 2012b). By 2013, RRI had become closely interwoven with both synthetic biology and STS.

Partly as therapy, partly as a form of reflection and analysis, Claire and I decided to write a paper about our experiences on the SBRCG. This raised a host of methodological and ethical questions about our position in the group and whether it was legitimate for us to write about our experiences at all—questions we decided to address directly in the paper. By choosing to write about the SBRCG, we put ourselves in the position of "turning relationships into data" (Mosse 2006, 937). This phrase could be interpreted benignly as a description of much qualitative research in the social sciences, but David Mosse uses it to describe an objectification of one's informants, which is very far from the idea of thinking *with* others, which was argued for in chapter 4.

Claire left the field of synthetic biology soon after the publication of the roadmap, but I remained heavily involved, benefiting directly from the funding it released. I was worried that publishing the paper with Claire would damage ongoing relationships with my synthetic biology colleagues because

I knew they regarded the roadmap as a significant achievement for the field. I felt under pressure to produce "an acceptable story that mediates interpretative differences in order to sustain relationships and the flow of resources" (Mosse 2006, 943). Because of my concerns, we decided to hold off submitting the paper for publication for several years, to wait until the roadmap was no longer such a politically charged topic.

Seven years later, in 2019, the paper was published online ahead of print. We directed it at the STS community because we wanted to share our experiences with other social scientists. In the paper, we said that our aim was "to tread a delicate path that simultaneously respects our ongoing participation in scientific, industry, and policy processes around synthetic biology and enables us to draw conclusions that we hope will be helpful to STS researchers as they increasingly find themselves in similar policy rooms" (Marris and Calvert 2020, 7).

What eventually emboldened me to publish the paper was not only its potential contributions to STS. I also felt some of the concerns it expressed came from within the synthetic biology community. The narrow economic framing of synthetic biology that was presented in the roadmap sat uneasily with the diversity I saw in the field. As noted in previous chapters, one of the distinctive features of synthetic biology in its early days was its opposition to the corporate monopolization of biotechnology and its attempt to imagine different, more open forms of innovation. At my presentation at SB7.0 in 2017 (see chapter 2), I had appealed to these features of the field, and to the discontent I had heard expressed about the directions synthetic biology appeared to be taking, to argue that things could be different.[18] This talk seemed to have resonated with many people in the audience, including my UK synthetic biology colleagues. I was also aware of the criticisms many of them had of the UK Synthetic Biology Leadership Council, which was established as a consequence of the roadmap. As discussed in chapter 5, there was unease with the restricted economic focus of this "select group of experts with a controlling stake in the technology."[19] I also considered the *Synthetic Aesthetics* book, and the way it had been interpreted by some as public relations for synthetic biology, to remind myself that my contributions to the field had elicited a diverse range of responses. All these factors persuaded me that we should publish the paper.

The online version of the paper was published in February 2019. A week later, one of my closest synthetic biology collaborators forwarded me (with no comment) an article in *Research Professional*, an online news outlet covering research policy in the UK, with the headline "Doubts over evidence for synthetic biology plan" (Gallardo 2019). I was dismayed to read the first paragraph:

> A government-endorsed roadmap for synthetic biology that has triggered more than £300 million of public investment since 2012 lacked evidence that the emerging discipline would generate the promised economic growth, according to two researchers involved in its development.

Claire and I were identified as the two researchers. The news article had picked up on one of the points we made in the paper that much of the roadmap was promissory rather than evidence-based. But the promissory nature of the roadmap had not been our primary concern in the paper. In fact, it was something we had somewhat taken for granted, given that all technology roadmaps are performative documents that chart paths to uncertain futures (McDowall 2012). The *Research Professional* article made it look as if the intention of the paper had been to undermine the promises made about the future potential of synthetic biology. And as I quickly learned, even though we had waited for years before publishing, this article came at a critical juncture for the field, just when the UK research councils were considering whether to reinvest in synthetic biology.

In the weeks that followed, I had discussions with some of my long-term synthetic biology collaborators about the paper itself. There was a range of reactions, from supportive to disinterested to disappointed to annoyed. Several synthetic biologists had been made aware of the paper through the *Research Professional* article, and reading it in that light, were worried it would have negative consequences for the future of synthetic biology in the UK, undermining it as a legitimate area of public research investment. Some said that the paper was too negative overall and that we should have given a much more positive interpretation of our involvement, since it was significant and unprecedented that social scientists were key contributors to a technology roadmap and that social scientific research was funded as a result. The comments that troubled me the most, however, were that social scientists would not be invited to be on similar committees again and that the intervention we had made by writing the paper might damage future relations between synthetic biology and the social sciences. This compelled me to acknowledge how highly I valued these interdisciplinary relations. Others said that we had an obligation to share our account, that we were on the right side of history and should continue to "fight the good fight."

These conversations were not always easy, but perhaps what is most significant about them is that they happened. Of course, we only had conversations with those who were interested in talking to us, so they do not necessarily reflect the full range of views of the synthetic biologists who were aware of our paper. But a selection of people did want to discuss, explore, and dispute our interpretations, and in doing so, they engaged with our text and with ideas from STS.

These conversations were also informative. They demonstrated how sensitive some of the synthetic biologists were to what they saw as challenges to the promises made for the field. They also reflected the iconic status the roadmap had assumed in the synthetic biology community, not just in the UK but also globally (e.g., see National Academies of Sciences, Engineering, and Medicine 2016). It became increasingly clear to me that because of my involvement in the roadmap, I had been part of the material (not just discursive) construction of a research field. Although Claire and I had not felt that we were in a powerful position within the SBRCG, perhaps we had underestimated the power we had just by being part of it. And the reason we were invited to be part of it was because we were considered to be members of the synthetic biology community; we were thought of as insiders, not social scientific observers. For some, it probably looked as if I had shifted from the position of a domesticated critic to an undomesticated one, and this perhaps explains some of the stronger reactions to the paper.

These strong reactions show the importance of affect in this context. Affect might seem out of place in discussing interpretations of a policy document, but for me, the 48 hours following the publication of the *Research Professional* piece were somewhat traumatic. By placing myself in the position of undomesticated critic, I had to confront the possibility that I would no longer be welcome in the field, that I would have to reorient all the research and teaching activities I had built up over the previous ten years, and that I would lose friendships I valued. After conversations with both STS and synthetic biology colleagues, these worries subsided, but the long-term consequences of writing the paper with Claire are difficult to predict. It remains to be seen whether we succeeded in treading a "delicate path" between participation in synthetic biology and contribution to STS knowledge.

This incident raises broader questions about the extent to which it is possible to write about the policy room without betraying the implicit rules of the space and preventing future access. By publishing our paper, Claire and I took a conversation out of one room and into another in a manner that might be regarded as transgressive. We were aware of this but chose to do so because we thought there were important things that needed to be said. Of course, many of these issues recur in this chapter, and in this book.

RESPONSIBLE RESEARCH AND INNOVATION IN THE POLICY ROOM

Stepping back from our paper and its interpretation and fallout, perhaps our most lasting contribution to synthetic biology via the roadmap was the introduction of RRI. As noted previously, the concept was already circulating in STS and policy communities at the time and has since become significant for both synthetic biology and social scientific involvement in the field. It has also become an important policy category and component of research governance, to such an extent that a discussion of STS in the policy room cannot ignore it. For this reason, I now turn to RRI and the way in which I think it can be most valuable in the policy room: to challenge dominant framings of innovation.

As an academic concept, RRI is a continuation of STS work stretching back several decades under various headings, such as constructive technology assessment (Schot and Rip 1997), upstream engagement (Wilsdon and Willis 2004), and anticipatory governance (Barben et al. 2008). But as a policy concept, it is more recent.[20] As noted above, RRI was emerging in policy spheres when we were writing the roadmap in early 2012, largely as a result of two workshops in 2011 organized by the European Commission (Owen, Macnaghten, and Stilgoe 2012), which made it a cross-cutting theme in the Horizon 2020 program later that year (Rip 2016). At the same time, the UK's Engineering and Physical Sciences Research Council (EPSRC) was developing interests in the area and formally announced its commitment to a framework for responsible innovation in 2013, citing the RRI section of the roadmap that Claire and I wrote as further reading on the topic (EPSRC 2013).

Over the next few years, key programmatic papers on RRI were published by a group of STS scholars (Owen, Stilgoe, and Macnaghten), and it is these papers on which I base my understanding of RRI, although interpretations of the term are contested, and there are others in circulation (see Rip 2016).

I draw on this group's work because of the question they put at the center of RRI: "What kind of future do we want science and innovation to bring into the world?" (Owen 2014, 114). This question resonates strongly with the notion of otherwising (discussed in chapter 6) because it is subjunctive and generative in its orientation toward possible futures. Another valuable aspect of this formulation of RRI is that it puts innovation and its governance center stage, so it is not only the practice of science but also "the political economy of universities and science" (Stilgoe and Guston 2017, 867) that is of concern. This means that insights from innovation studies and science policy become increasingly relevant (Zwart, Landeweerd, and van Rooij 2014).

Drawing on this work, I would maintain that one of the most important ways in which RRI can be used in the policy room is as a lever to open up dominant understandings of innovation and put forward alternatives. This argument resonates with the Nuffield Council on Bioethics report on *Emerging Biotechnologies* described in chapter 6. Although the report did not use the language of RRI, it drew attention to narrow economic framings of emerging biotechnologies and demonstrated that they could be framed differently.

STS scholars have written on why dominant framings of innovation should be challenged. They argue that these framings benefit incumbent interests and market forces (Macnaghten 2016; Stilgoe and Guston 2017), and since the market operates according to the logic of increasing returns, this produces lock-in and path dependency (Callon 1994). Classic examples of lock-in include the QWERTY keyboard and petrol-driven cars—both problematic technologies that have nonetheless achieved a predominance that is difficult to overturn. In this sense, the market is "a powerful machine for constructing irreversibility and limiting the variety of technological options" (Callon 1994, 410). This feature of the market is particularly problematic given the uncertainty of scientific and technological developments. Since we cannot predict in advance the optimum pathway for such developments, the argument is that we should instead foster diversity, which offers multiple ways forward (see also Nuffield 2012).

Relatedly, many innovation studies scholars have shifted in recent years from a blanket pro-innovation position to one that asks: "Could it be that innovation is not always good for you?" (Soete 2019, 855). They note that technological innovations often have detrimental consequences for both the environment and social welfare (Soete 2019). All these factors combine to produce what Richard Owen describes as "the tragedy that is the hegemonic framing of innovation in Western industrialized society . . . tied to a political economy based on markets, competitive destruction, the creation of value, consumption and never ending growth." This produces a system that is "ultimately unsustainable: ecologically and socially" (Owen 2016).

This leads to calls to reframe innovation, to conceive of it in different ways. Stevienna de Saille and Fabien Medvecky (2016, 7) argue that rather than understanding it in a conventional economic manner as the process of bringing something new to the market, we should see innovation as "the process by which novelty is taken up and circulated in the public sphere . . . producing some kind of profound re-ordering of what-has-been." Innovation, understood in these terms, can "reconfigure the existing states of the world" (Callon 1994, 416).

It is not just the word "responsible" that is being used to modulate notions of innovation. We have also seen the rise of ideas such as inclusive innovation (Rip 2016), social innovation (Moulaert, MacCallum, and Hiller 2013), open innovation (Chesbrough 2003), distributed innovation (von Hippel 2005), sustainable innovation (Leach et al. 2012), slow innovation (Steen and Dhondt 2010), and frugal innovation (Sigl 2016)—forms of innovation that do not necessarily emerge from novel science and technology. Although identifying new types of innovation is not necessarily an easy fix for the pathologies of market-driven innovation (Parthasarathy 2019), these new variants indicate a turn toward directionality in innovation, showing that economic values do not always have to dominate (Joly 2019). And, as noted previously, one of the things that drew me to synthetic biology in the first place was its openness to different ways of thinking of innovation.

All this encourages reflection on what constitutes responsible *innovation* by drawing attention to its potential diversity. This is something STS and innovation studies researchers have attempted to instigate in a variety of contexts, bolstered by the literature outlined above. It is a difficult task, however, and I would not say I succeeded in it in either of the policy rooms discussed in this chapter.

More worryingly, RRI is increasingly being used to legitimate activities that do precisely the opposite—solidify dominant framings of innovation to achieve economic objectives (de Saille 2015) or "grease the wheels of technological progress and foster the advancement of the bioeconomy" (Felt 2018, 112). This is represented by the way in which RRI was seamlessly incorporated into the roadmap recommendations in the phrase "Invest to accelerate technology responsibly to market."

RESPONSIBLE RESEARCH AND INNOVATION AT DIFFERENT LEVELS

Despite the difficulties of challenging dominant framings of innovation in the policy room, I do think it is at this level—the level of the economics and politics of research policy—that RRI is most valuable, because, like Stilgoe, Owen, and Macnaghten (2013), I see responsibility as a feature of systems. However, as the concept has become more widespread, it has been increasingly pushed down to the microlevel—to the level of a social scientist delivering RRI for an individual research project. The appeal of this for scientists and engineers is clear—involving a social scientist with "responsible" in their job title in a scientific project shows that an attempt is being made to ensure that the project and its outputs are responsible. But it means that in many circumstances, RRI has become interchangeable with ethical, legal, and social implications (ELSI) and mired in all the problems associated with ELSI. As discussed in previous chapters, ELSI implies a separation of facts and values that delegates responsibility for values to social scientists or bioethicists in a manner that does not challenge the scientific work of producing facts, resulting in a situation that is comfortable and containable (Felt 2018). This is very different from interrogating "the political economy of universities and science" (Stilgoe and Guston 2017, 867).

As demonstrated in the coffee room and art studio (chapters 4 and 5, respectively), I think the most productive interactions between social and natural scientists at the microlevel are experimental collaborations, which are not driven by an externally imposed agenda but instead involve thinking *with* others. Such experimental collaborations can result in innovation, if innovation is conceived of as bringing something new into the world. Experimental collaborations require that all those involved are open to each other's perspectives, so if we understand responsibility as the capacity to respond to others—to be "response-able," to use Haraway's (2008) term—then we can build links between experimental collaborations and RRI by embracing opportunities for learning with others across disciplines and professions in a manner that is far removed from ELSI and its associated division of labor.

THE SIGNIFICANCE OF THE POLICY ROOM

What counts as RRI in which contexts is currently contested, but this has not stopped STS, RRI, and synthetic biology from becoming tightly interconnected, primarily at the level of the scientific research project. I have argued here, in contrast, for the importance of RRI at the policy level. This raises a broader question of relevance to this book as a whole: whether the policy room is the room from which STS researchers are most likely to have an influence on science and technology.

Joly (2015) argues for the significance of STS work in this space. He maintains that the scientific research project may not be the most productive site for STS engagement because attempting to harness and promote the reflexivity of scientists and engineers in places like the laboratory is of little consequence in the context of the huge pressures that they are under to acquire competitive funding and to demonstrate the commercial potential of their research. He argues that as social scientists, we need to be more attentive to "the diversity of processes that operate at different scales" (Joly 2015, 236), which may involve shifting our focus from the microlevel to the level of the politico-economic. Such a shift is described by Webster in his 2007 paper discussed above. He moved to the policy room because the lab study he was conducting did not allow him to develop a critique of the privatization policy that was becoming increasingly consequential for the lab's operations. This resonates with points made in chapter 1, on the laboratory, that a microlevel study may overlook structural factors such as funding priorities and intellectual property regimes, which determine the conditions within which scientists and engineers operate. It may be that when it comes to intervention, the policy room is the best place for STS.

Indeed, one of the attractions of the policy room is the possibilities it provides for intervention, as noted at the start of this chapter. But my experiences in the two policy rooms discussed here have shown that intervention was far from easy in these spaces. The work of the BSS panel was best described as slow and sustained attrition. It could perhaps be understood as a form of "soft intervention" or "modulation" (Fisher and Rip 2013), which pushed for greater reflexivity (Rip and Robinson 2013; see also chapter 1, on the laboratory, and chapter 3, on the classroom). Everything we did, however, was restricted by BSS's position within the BBSRC, an organization that exists to fund and promote the life sciences, and the BBSRC's position in turn within the economic structures of the UK government. In the case of the SBRCG, it could be argued that Claire and I successfully intervened by inserting a section on RRI into a prominent policy report. But we felt particularly constrained in this room, with its top-down, narrowly defined remit and short timescale.

Both of these rooms contrast with the Nuffield Council on Bioethics working party on Emerging Biotechnologies. The autonomy of the bioethics building that housed that group allowed for independent critical analysis of prevalent political and economic ideas about biotechnologies and why they should be funded. But the downside of its external positioning was that the report we produced could be (and was) largely ignored. The Synthetic Biology Roadmap, in contrast, initiated an influx of funding into synthetic biology, some of which went to RRI.

As noted previously, the boundaries between the bioethics building and the policy room are blurred. It is possible for national bioethics bodies to be embedded within government structures and for funding committees to have significant institutional independence. As Helga Nowotny (2007, 480) points out, the phrase "policy room" encompasses a diversity of different spaces, and while some are at the highest levels of government, there are "other rooms below the upper floor." This suggests it is necessary to adopt a more nuanced understanding of the different types of policy room and the kinds of intervention they allow.

EXPLORING INTERVENTION

This raises larger questions that I have elided so far about what exactly is meant by intervention and what type of intervention I was making in the policy room. Zuiderent-Jerak (2016), who has explored the topic in depth, shows that one-way intervention can be understood in terms of achieving predefined normative goals. This type of intervention, which might involve taking a particular stand in a controversy,[21] connects to the activist strand of STS work that originated in social movements in the 1960s. This understanding of intervention does not capture my engagements with policy, however. Although I did sometimes attempt to direct discussions in particular ways in the policy room—to shift understandings of public engagement away from a deficit-model framing, for example—this did not serve predefined normative goals.

Zuiderent-Jerak (2015, 73) puts forward an alternative notion of intervention—"experimental intervention"—which he describes as "a *scholarly method* for producing novel insights about our topics" (emphasis in original).[22] This involves changing practices in order to learn from them and develop social scientific theory. But again, this does not describe my work in the policy room. I did not intervene with the conscious objective of attempting to gain knowledge from these interventions, although knowledge—primarily about the difficulties of intervening in this room—was acquired along the way.

A useful way to understand intervention is to contrast it to collaboration. This contrast marks the difference between my interactions in the policy room and those described in the coffee room (chapter 4) and the art studio (chapter 5). While collaboration involves thinking *with* others, in the policy room there were some people I was thinking *against*; I was disagreeing with them and challenging their positions. The word "intervention" comes from the Latin *inter*- (between) and *venire* (to come), so it carries with it "a strong undertone of 'coming between', or 'interrupting'" (Freeth 2019, 133), which is very different from the co-laboring of collaboration.

Although many of my interventions in the policy room were unsuccessful, this does not mean they were not interventions. As Zuiderent-Jerak (2015, 35) puts it, "The tension of striving for change while realizing that it will turn out differently than intended cannot be resolved." Some might think that practicing a form of intervention that does not have predetermined normative goals or expectations of success is unsatisfactory. Wynne (2007, 493), however, pushes for even fewer expectations; he argues that STS researchers should engage with policy in a way that "demands no manifest influence."

Wynne makes this argument in a paper that is a response to Webster's article on STS in the policy room. He talks of his discomfort with STS work that is "geared to influence policy-decision outcomes" (Wynne 2007, 491). He argues instead that the role of STS should be "that of questioning the dominant (usually hegemonic, taken-for-granted) framings of the meaning of public issues involving science and technology" (494). This involves engaging with and speaking critically to the policy world but without the expectation of "instrumental policy influence" (494).

Wynne's description of STS involvement in policy fits well with my attempts to challenge narrow framings of innovation and encourage institutional reflexivity. He makes a strong case that this “confrontation of culturally entrained taken-for-granteds” (Wynne 2007, 500) is something that STS is particularly well placed to do because of its “radically reflexive” (501) research agenda, which shows that things could be otherwise (to put it in my terms). Wrestling with the power of the innovation discourse is perhaps the most important role for STS in the policy room (Pfotenhauer 2019). Wynne notes that this requires a longer-term horizon than is normal for policy-engaged STS work, meaning that the discrete policy encounters described here can only be understood as small parts of a larger endeavor. He also argues for the value of “reflective historical work, which delineates the contingent ways in which existing policy and technoscientific cultures have become entrenched” (Wynne 2007, 491). Although not strictly historical, my paper with Claire could be seen as an example of this type of work, written without an expectation of influencing short-term policy decisions but an intervention, nonetheless.

SCIENCE AND TECHNOLOGY STUDIES IN THE POLICY ROOM

The two policy rooms that I have discussed in this chapter are very different, but their comparison helps reveal the constraints and opportunities provided by this space. It shows that the initial conditions of one’s involvement matter and that time is an important consideration, both in terms of when one enters a policy room and the time pressures that apply once one is there. The longer-term and more open-ended engagements in BSS made this room more suited to STS involvement than the SBRCG, but even here it was very hard to unsettle the BBSRC’s assumptions about the relations between science, the public, and the economy.

In other chapters, I have shown the value of being in a room with an STS colleague, but because of the constraints encountered in the policy room, it is particularly important not to enter this room alone. Wynne (2007, 497) argues that his experience on a food policy committee was frustrating largely because “acting without any STS allies, I was utterly unable to diversify existing entrenched ideas about innovation and future expectations.” Max Liboiron (2016) also points to the importance of “buddies” who “have your back” in interventionist STS research (see also Viseu 2015). I found allies easily in the interdisciplinary multistakeholder group that comprised BSS, but in the high-profile roadmap group, the contributions that Claire and I made would have had far less weight if we had not both been there to reinforce each other's points.

I would also not have been emboldened to write critically about these experiences without Claire as my coauthor. But it is significant that the writing and publication of our paper took place outside the policy room. We made this room into an object of research, shifting to the position of observers, drawing on our experiences for our analysis. The strong reactions to the paper show the tensions that can arise when moving between different methodological orientations in this way. The paper's publication is a test of whether it is possible to sustain collaborative relations with synthetic biologists in some spaces—like the coffee room and the art studio—while being critical in others.

The policy room can demand much time and energy from those who enter it, and this does not necessarily translate into either policy outcomes or academic credit. I do think the policy room can be a significant place for STS, however, because it provides opportunities to intervene at the level of research agendas and funding strategies and influence the political and economic context in which research is conducted, which is not possible from most of the other rooms discussed in this book. There are downsides to the policy room, too, of course. Its formality and urgency can give it a semblance of importance, when much of the time one's activities are limited by the conventions of the space. And although there is the capacity for intervention in the policy room, this chapter has shown that these interventions will not necessarily take a predictable form, and we are likely to have little control over their consequences.

This shows the value of Wynne's call for STS engagement with policy that does not demand or expect manifest influence. Such an orientation makes it possible to interact with, but not become absorbed into, this sharp-suited world and to calibrate our policy work by spending time in different spaces. It is a reminder that science and innovation policy is something that can be studied in other contexts and in nonengaged modes. This more detached form of scholarship is the topic of chapter 8, on the ivory tower, the final room I explore in this book.

8 THE IVORY TOWER

Unlike the other rooms discussed in this book, the ivory tower is not a real place, but it is a powerful metaphorical one. A tower reaches up to the skies; it can be a vantage point or a defensive stronghold.[1] A tower made of ivory conjures up many associations and connotations. Shapin (2012) analyzes its changing cultural reference, from a place for religious contemplation stretching back to biblical times, to a site of artistic sanctuary in the nineteenth century, to its current association with science and the university, which it only acquired just before the Second World War. In all these guises, it stands for detachment, separation, and isolation from external others and external demands, allowing for reflection and the pursuit of knowledge.

In this chapter, I exploit the multiple meanings of the ivory tower to explore two aspects of it. Although they cannot be cleanly separated, attempting to distinguish them can be useful in thinking about a place for science and technology studies. The first is the ivory tower as the disciplinary academy. This can be a conservative and exclusionary place, which incentivizes certain types of academic activities and is not always hospitable to the interdisciplinary collaborative researcher, particularly one who identifies with an uninstitutionalized field like STS. The second is the ivory tower as place of retreat and contemplation—represented by the library or the study. Understood in this sense, the ivory tower provides not only spatial but also temporal separation and offers opportunities to pause and slow down. This draws out a point that applies to all rooms: that time and space are intrinsically connected.

Throughout the chapter, I consider a more detached form of scholarship than I have in previous chapters. I describe my deliberate move away from collaboration, intervention, and a situation of constant fieldwork. This was a methodological experiment of sorts that I undertook to explore the consequences of removing myself from synthetic biology, to have time and space to process my data and experiences, to reflect and to write. I wanted to understand the value of not doing interdisciplinary work, not becoming complicit, not getting involved. This methodological experiment was unexpectedly extended, giving me an opportunity to reflect on the differences between withdrawing to the ivory tower and withdrawing to one's home. I conclude the chapter by arguing that although the ivory tower often connotes a place of privilege that is not free of interests, it can be a valuable space to spend time in, but only if one is not a permanent resident there.

THE DISCIPLINARY ACADEMY

Today, some people simply use the ivory tower as shorthand for anything that happens in a university (which would encompass most STS and most synthetic biology, for that matter). Others contest this, and argue that universities are not, and have never been, ivory towers; they have always been politicized and deeply connected with church, state, or market (Shapin 2012). For others still, the ivory tower is simply a term of abuse, applied to imply that academic work is indulgently irrelevant and disconnected from the world. In these various ways, the university is the institution that we currently associate most strongly with the ivory tower.

Some of the more constraining features of this institution are brought to the fore if one is a researcher who traverses disciplines. And STS is rather radical in its interdisciplinarity, given that it spans the humanities, the social sciences, and the natural sciences (Müller 2017). Since different disciplines have different expectations, reward systems, and assumptions about what constitutes good work, STS has an uneasy relationship with the disciplinary academy, and this is exacerbated when the STS work is highly collaborative.

Traditional disciplines are very powerful in most universities. They normally control the structure of departments as well as hiring and promotion. Since there are only a handful of STS departments globally, the majority of STS researchers are located in more conventional disciplinary contexts and are compelled to conform to disciplinary norms. In the US, this situation can be exacerbated by the pressure to secure tenure. In the humanities and much of the social sciences, tenure often requires a monograph, and in all fields, it necessitates a departmental home. Because of these pressures, the expectations placed on STS researchers in many universities in the US tend to fall along traditional academic lines (Kattirtzi and Stirling 2018). In the UK and Europe more broadly, academic reward is often based on acquiring third-party funding (Felt 2017). This funding is often for large, multi-institutional collaborative projects, which has made a difference to how STS has developed and how careers are organized in Europe.[2] But more traditional academic pressures still apply in Europe, and pressures to acquire funding are also present in the US, so many researchers find themselves pulled in multiple directions.

It is not surprising that STS does not fit easily in the disciplinary academy since it analyzes the historical contingency of disciplines and critiques their epistemic coherence. This is one of the reasons why there is reluctance to establish STS as a new orthodoxy (Mikami and Woolgar 2018), a discipline of its own that would find a comfortable home in the ivory tower. In fact, Stirling maintains that "STS has all the tools and sensibilities and practices and culture necessary to look afresh at disciplines" and that it could instigate radical changes in the way academic research and pedagogy are organized (Kattirtzi and Stirling 2018, 401). Such changes would not leave the ivory tower intact.

Another challenge STS faces in the disciplinary academy is that an increasingly large proportion of STS researchers are on short-term contracts funded by external grants (Garforth and Cervinková 2009; Siler 2012). This is already a prominent characteristic of the labor market in the natural sciences and engineering, as chapter 1, on the laboratory, showed. This significant group of researchers has a precarious existence in the disciplinary ivory tower. The situation is exacerbated in STS because the funding for these posts often comes from a scientific research grant, and there is unlikely to be more than one STS researcher working alongside the scientists and engineers. There are no clear career paths for these embedded researchers in the traditional structures of academia.

For these reasons, those STS researchers who do have relative job security often attempt to secure funding to create postdoctoral positions for early-career colleagues that will afford them some kind of autonomy. This is something I have done myself, applying for grants in which I argue that it is important that reflexive and critical STS research into synthetic biology is not wholly reliant on funding from science and engineering and that dedicated social science funding enables both close engagement with the field and academic independence. In a sense, I have attempted to carve out a protected space for STS research within an academy that does not seem to provide such protection.

I have sometimes been successful in these attempts, as have other STS researchers around the world (in fact, this book only exists because of funding specifically for social science research, for which I am immensely grateful).[3] But this will always be an uphill battle. The pressures and constraints of the disciplinary academy remain. The volume of research funding in the natural sciences and engineering is much greater than that in the social sciences and humanities, and the structural dependency many precarious STS researchers have on these better-funded disciplines is unlikely to change.

TEMPORALITY

This structural dependency and the sustained interdisciplinary engagement it requires means early-career STS researchers have less time to dedicate to academic pursuits that have greater institutional recognition, such as high-profile publication (Müller 2017). There is also a danger of asynchronies in interdisciplinary work because the humanities, the social sciences, and the natural sciences operate on different timescales. As Anne Beaulieu and colleagues (2007, 679) note, "humanities scholarship has an altogether different rhythm" from the natural sciences both in terms of reading and writing, because lengthier, more sustained pieces of work are the norm. The social sciences usually stand between these two extremes, but the time it takes for social scientific work to be published is usually much longer than it is for the natural sciences, which can cause problems for embedded STS researchers who may be seen as unproductive (Balmer, Bulpin, and Molyneux-Hodgson 2016). The natural sciences tend to move faster in general, and synthetic biology is a field that moves very quickly; papers are churned out rapidly, and grants are applied for continually. This is not only part of the culture but also an externally imposed expectation of funding agencies that places considerable pressure on the scientists and engineers. Collaborating with synthetic biologists involves being caught up in the speed and urgency of the field, which is undeniably part of the thrill of it too.

I have discussed the combination of thrill, speed, and discomfort that I have experienced in synthetic biology spaces in previous chapters, and argued that it is the feeling of urgency that often accompanies embedded work that gives it much of its almost addictive appeal. But time pressures are not only experienced in collaborative work. Some argue that "a culture of speed frenzy" (Müller 2017, 88) has taken over academia more broadly and that the acceleration of science is one of the most prominent aspects of academic experience (Garforth and Cervinková 2009). Across the board, academics are increasingly reporting that they have no time to think or read, no time for reflection and immersion in their work. What we see instead is an "emphasis on the speedy, effective, regulated and regimented production of tangible, measurable, quantifiable and rateable outputs" (Bristow 2012, 238).

Such time pressures can have unintended consequences. Mark Carrigan (2015) warns that they "can reduce the time available for reflexivity, 'blotting out' difficult questions in a way analogous to drink and drugs," limiting our capacity for imagination and deliberation, and encouraging us "to accept things as they are rather than imagining how they might be." In this context, Jacques Derrida's (1983, 19) comment that "the internal rhythm of the university apparatus is relatively independent of social time and relaxes the urgency of command" seems extremely anachronistic. Balmer and Bulpin (2013, 331) even argue that pausing can be a political act in academia today, "a form of resistance to extant pressures shared across the natural and social sciences."

TIME AND WRITING

This brings me to the temporality of writing a book, which requires long-term sustained effort and stretches of time free of other commitments. This is not only inconceivable for the contract researcher but often implausible for any researcher engaged in collaborative or interventionist work. It is notable that many of the leading (European) STS scholars that I repeatedly cite in this book have not prioritized the single-authored monograph form. Furthermore, journal articles are a more appropriate currency than books in the accelerated academy. Articles are "seen to be a better fit with the temporal and counting logic of funding agencies and universities, and to offer a more immediate short-term return on investment" (Felt 2017, 55). This logic has infiltrated the natural sciences and engineering to the extent that any serious academic contribution in these areas takes the form of a journal article.

But books allow a more extended treatment of an issue and a more cumulative narrative to be constructed. And perhaps, buried in the pages of a book, one can sneak in odd or tentative ideas or get away with being more personal or playful than one could in a journal article. One of my motivations for choosing this longer form, as noted in the introductory chapter, is that I struggled to find literature to make sense of what I was doing as an embedded STS researcher. Another was that I had the opportunity to step away from my engaged work and its urgencies, to explore the affordances of both temporal and spatial separation. I was free to enter the second incarnation of the ivory tower that I discuss in this chapter, represented by the library or the study.

EXITING

It is common for a social scientist to leave their fieldsite in order to write about it. It is often assumed that a period of data gathering ("ethno") is followed by a period of writing and analysis ("graphy"). In STS terms, this has been described as a shift "from lab to library" (Aguiton 2011). There is also a practical aspect to leaving the field: If one is in a situation of continuous fieldwork, one is attempting to analyze a situation that is constantly changing. Exiting draws a line under the empirical research. Writing can itself become a form of separation and detachment, a way of creating spatial and temporal distance between the field and the researcher (Mosse 2006). In the case of synthetic biology, Rabinow and Bennett, anthropologists whose involvement in the Synthetic Biology Engineering Research Center has been discussed in previous chapters, only published their book on their experiences after they had left the field (Rabinow and Bennett 2012).

I was initially concerned about the prospect of stepping outside synthetic biology. I found it hard to imagine not attending the key conferences and workshops, not contributing to the continuous flow of research grants being submitted and giving up valuable opportunities to learn more about the field. Most importantly, I was embedded in ongoing relationships, and it was neither straightforward nor desirable to terminate them. Mosse (2006, 937) shows that this situation is not unusual; for anthropologists who study professional communities, "the relationships of the field persist" and "the capacity to exit through writing is in question." With my STS colleagues, I had spent many years building relationships of collegial obligation and reciprocity with the synthetic biology community. As discussed in chapter 7, the prospect of being excluded from the field was somewhat traumatic; leaving it voluntarily was not a natural step.

I did enter the ivory tower, however, on the grounds that this was an opportunity for a methodological experiment, a chance to spend time in a different kind of room. But it was only because I had funding that I could even contemplate this kind of retreat and disengagement. The funding allowed me to take research leave and freed me from teaching and administrative commitments. This shows the strong connections between financial resources, time, and writing. As Virginia Woolf (1929, 103) famously told female undergraduates in *A Room of One's Own*, "it is necessary to have five hundred a year and a room with a lock on the door if you are to write fiction or poetry."

To be specific, the ivory tower that I retreated to was the University of Leipzig's Bibliotheca Albertina, a grand neo-Renaissance-style library originally built in 1891 (see figure 8.1). The main doorway in the impressive facade of the Albertina opens on to a wide marble staircase leading up to the central reading room with large arched windows. As I spent time in this high-ceilinged contemplative space, my connections to the synthetic biologists decreased. The conference invitations slowed down and then virtually stopped—although this was also because in 2019, synthetic biology was no longer the hot topic it had been ten years earlier. The separation was not as difficult as I had anticipated.

THE LIBRARY

The library is a place of solitude, in contrast with all the rooms discussed in previous chapters. It is a place not only of physical but also of temporal separation because going to the library involves a commitment to making time for a particular type of work. This demonstrates the point that there is a necessary connection between time and space in all rooms simply because being in a space requires time. It follows that multi-sited ethnography is necessarily a time-consuming exercise.

The connection between space and time is also found in the word "contemplation," the root of which is the Latin word *templum*, meaning a sacred piece of ground. This implies that demarcation from ordinary time and space is necessary to give attention to what matters, and that knowledge or perhaps even wisdom can be found by spending time in particular locations (Wheater 2021). The strong religious connotations here connect back

FIGURE 8.1
The central reading room of the Bibliotheca Albertina. *Source*: Photograph by Jane Calvert.

to the historical roots of the idea of the ivory tower as a place one enters to get closer to the divine (Shapin 2012). It is no coincidence that libraries often resemble churches or cathedrals.

The religious associations of the ivory tower may have dissipated, but many still emphasize the importance of distance and separation for the generation of knowledge. For example, drawing inspiration from Max Weber's famous 1917 lecture "Science as a vocation," Lynch (2009, 106) argues that the academic vocation "requires institutional distance and temporal leisure from political and economic arenas" because this "provides space for reflection, which gives rise to non-standard modes of interpretation and criticism." This resonates with the idea that those who retreat can arguably gain "insights devoid of parochial particulars" (Livingstone 2003, 21) by distancing themselves from others' points of view (Ophir 1991). In fact, such stepping back could be seen as a form of otherwising, since it can provide "a heightened awareness of taken-for-granted assumptions" (Lynch 2000, 30). At first glance this may appear to challenge the argument made in chapter 6, on the bioethics building, that "otherwising requires others"—people from diverse groups who bring with them a disparate range of views. But the point here is that remote others are still present in field notes, interview data, and published work.

Relatedly, it may seem strange to describe a place of separation as a place of observation, but the library allows for reflective observation of one's data and experiences. Again, the temporal dimension is crucial here. Observation in the library is recollection of what has passed, which is why some kind of exit and separation is necessary.[4] The library allows for "a hiatus between the eye and the mind—between looking and writing" (Ophir 1991, 176), between observation and reflection.

It could even be argued that the library is a place for intervention. Not the type of intervention from within a scientific field that can take place in the conference room, but the type of intervention argued for by Wynne (2007) and discussed in chapter 7, which questions dominant framings and demands no manifest influence. The critical distance (both spatial and temporal) provided by retreating and disentangling oneself from one's fieldsite may well be necessary to identify and critique existing power structures and make significant interventions (Joly 2015), as Claire Marris and I attempted to do in our roadmap paper. And writing itself can be thought of as a "hopeful intervention" (Riley 2019, 16) with potential longevity.

It would be too much of a stretch to try to claim that the library is a place of interdisciplinary collaboration, but this can even be considered one of its attractions. It is a reminder of the point made at the end of chapter 7 that topics like science and innovation policy can be productively studied in nonengaged modes. For example, there is STS work that maps the field of synthetic biology using bibliometrics (Oldham, Hall, and Burton 2012) and patent analysis (Ribeiro and Shapira 2020). Much valuable philosophical work on the nature and properties of synthetic biology is similarly not dependent on collaborative relationships with scientists and engineers and draws its conclusions primarily through analysis of the scientific literature (e.g., Boudry and Pigliucci 2013; Lewens 2013; Preston 2008).

But the lack of collaboration is also a problematic feature of this space. I have argued in previous chapters for the value of experimental collaboration: of thinking *with* epistemic partners, being part of shared projects and initiatives, challenging each other's assumptions, and creating something new together. Despite my concerns about becoming complicit and overly involved, collaboration is something I am reluctant to give up. Furthermore, as Estalella and Sanchez-Criado (2015, 304) argue, "experimental collaborations unfold other forms of knowledge production different from the heroic and lonely individual research that social science methodologies have sanctioned for decades."

Heroic and lonely research that involves removing oneself after spending time in the field could also be argued to be ethically remiss. In chapter 7, I grappled with the question of whether one should be involved in extracting knowledge from others and then going away to write it up for one's own benefit. Returning again to the importance of time, in all empirical research there is an obligation to those who are willing to share their time and thoughts, because when we engage others in dialogue, "we are spending their time and attention which could have been directed at something else" (Horst 2013, 39).

Recognizing these limitations, I nevertheless retreated for the best part of a year to Leipzig and wrote the majority of this book. I returned to Edinburgh in early 2020 and started writing this chapter in March 2020, when everything changed. The UK, along with a large proportion of the world's population, was put into lockdown because of the coronavirus global pandemic. All but essential businesses and services were closed, and everyone was confined to their homes. On a good day, the birdsong was louder than the sirens.

THE HOME

In some senses, writing about the ivory tower from the confines of one's home is very appropriate. Like the ivory tower, lockdown requires retreat and isolation. It is also temporally disruptive, and, like many others, I experienced a changed perception of time during this period (Schnalzer 2020). Initially, slowness seemed to be permitted because of the cancellation of all face-to-face meetings and events. This led some to argue that the crisis provided a unique opportunity to "slow down the pace of academia" (Corbera et al. 2020). But after the novelty of lockdown faded, the almost identical days sped by surprisingly quickly. Deadlines still loomed, teaching and supervising still needed to be done (online), and the financial precarity of the university system across the world became increasingly clear.

The home and the ivory tower might superficially seem to share the feature of being places of private sanctuary. But retreating to the ivory tower is not the same as spending time at home. Although one works alone in the library, it is a public space with particular expectations about acceptable behavior. And the ivory tower in all its forms is a place for dedicated intellectual pursuits, not for cooking, cleaning, and caring—the kinds of domestic activities that became central during lockdown.

Domestication is a theme that has arisen in previous chapters. In the laboratory and the conference room chapters, I showed that it was possible to be domesticated by a space by taking on board its norms and limitations, being "tamed" by it, and having one's critical capacities blunted by spending time in it. I used the idea of domestication to describe a process in which one comes to feel increasingly at home in another environment. But when one is compelled to work from home (*domus* in Latin), one is already in a situation of domesticity, a kind of domesticity that is highly gendered and strongly associated with the private sphere. As Hilde Heynen (2005) points out, this association is relatively recent; it was only with the rise of industrial capitalism and imperialism in the early nineteenth century that the home became opposed to the workplace. The home does not necessarily lend itself to solitude and contemplation like the ivory tower. This is why Woolf (1929, 109) insisted that a woman not only needed a room of her own and independent finances if she wanted to write, but also "a lock on the door."

During lockdown, for those of us lucky enough to be able to work from home, the home/workplace distinction was challenged and domesticity enforced on all. In some ways, the home became less of a private space than it had been previously because of the multitude of virtual interactions, through which colleagues could observe each other's interior design choices, partners, children, and pets. The kitchen of my top-floor flat in Edinburgh doubled as my office space, with my webcam directed away from the fridge and toward a conveniently positioned bookcase.

It was during the early weeks of enforced isolation that I came to particularly value the biweekly online synthetic biology seminars run by my Edinburgh colleagues and open to everyone on their mailing list (a virtual tie I had not cut). These seminars were both collegial and informative about the pandemic. Through them, I learned that many of the scientists had quickly repurposed their research facilities to scale up mass testing. Such activities could hardly be further from ivory tower contemplation; the synthetic biologists were responding directly to a pressing social need.

Situations of national and global crisis often present challenges to towers made of ivory, which is, after all, "a noble but impractical building material" (Ilynska, Ivanova, and Senko 2016, 89). The philosopher Bertrand Russell's reflections on the aftermath of the Second World War could have been written about the 2020 pandemic: "In a world such as we now live in, it becomes increasingly difficult to concentrate on abstract matters. The everyday world presses in upon the philosopher and his ivory tower begins to crumble" (Russell quoted in Shapin 2012, 18). Seeking refuge in the ivory tower in the face of global catastrophe seems highly inappropriate. And writing *about* the ivory tower might be considered even more so.

THE IVORY TOWER AS A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

I do think it is important to consider the ivory tower when exploring the question of a place for STS, however, because the vast majority of STS researchers are based in universities. As I have argued, the ivory tower understood as the disciplinary academy, with its established reward systems and entrenched disciplinary norms, is in many ways not a good location for STS, which is an interdisciplinary field that has little institutionalization and a large proportion of researchers on temporary contracts. But when the ivory tower is understood as a library, a place of contemplation and retreat—both from the demands of collaboration and from the time pressures of academia—it becomes a much more attractive location. It can allow for a reflective form of observation, for otherwising (with remote others), and for interventions through writing. It would be tempting to conclude that the library is an excellent location for critical and reflective STS work, albeit without the novel opportunities offered by experimental collaboration. But this is where the boundaries between my two types of ivory tower start to blur. One has to be in a position of institutional security to spend extended time in the library, to engage in solitary pursuits, and to voluntarily cut oneself off from the sources of funding that interdisciplinary collaborations can provide. Many STS researchers do not have this luxury.

I have been able to oscillate between these different understandings of the ivory tower because of its indeterminacy and flexibility, which owes much to the fact that it does not actually exist. As Shapin (2012, 13) puts it, the ivory tower is "an encouragement to live and produce knowledge in one way rather than another—not a type of place people could inhabit, even if they wanted to." In fact, it might be better to understand the ivory tower as more temporal than spatial: as "a phase, a moment in the making of knowledge and virtue" (Shapin 2012, 15). But this phase is a crucial one, because both engagement and disengagement are necessary in STS work, and neither is sufficient on its own (Müller 2017). This makes it necessary to persist in attempting to provide opportunities for institutionally precarious STS researchers to spend time in the ivory tower while acknowledging that it will only ever be a "temporary refuge" (Lynch 2009, 114). As with all the other rooms discussed in this book, what one gains from spending time in it is enhanced by the contrast with other settings. In the next and concluding chapter, I explore the consequences of this itinerancy.

CONCLUSIONS: TOWARD A COLLABORATIVE SCIENCE AND TECHNOLOGY STUDIES

An itinerant science and technology studies researcher does not have a room of their own; instead, they move from room to room. In this way, they become a liminal figure. Liminality is a notion that is particularly appropriate to the discussion of rooms because in Latin *limen* means "a stone placed on the threshold of a door that physically had to be mounted in order to cross from one space into another" (Szakolczai 2009, 152). In this sense, to be liminal is to be on the edge, to be simultaneously an insider and outsider (Downey and Dumit 1997; Eyben 2009). One of the most well-known mythical liminal figures is Hermes, "the winged god of boundaries, events, movement, translation, transformation, and invention," who shifts between "the realms of gods and mortals, the living and dead" (Stenner 2015, 311). Despite the appeal of becoming a Hermes-like STS figure, there are drawbacks to such liminality. One might be regarded as transgressive, or even dangerous, by betraying the implicit rules of a particular space (Eyben 2009)—something I experienced when publishing on my experiences in the policy room. Another issue is that the "constant calibration" (Rabinow and Bennett 2012, 177) involved in moving between multiple sites is necessarily accompanied by "a relinquishing of certainty and control" (Humphrey 2007, 23).

Liminality requires a methodological position of being "adjacent" to scientists and engineers (Rabinow and Bennett 2012). In other words, it requires the capacity and resources to remove oneself from any one particular research site, which can often be difficult for STS researchers attached to large scientific research grants (Viseu 2015). This makes it particularly important that there is a place for STS for the itinerant researcher. I like to think of this place as a safe harbor we can return to, where we can share our experiences and concerns, learn from mentors and support colleagues, and feel "intellectually and socially 'at home'" (Felt 2009, 19). Such temporary shelter and replenishment will embolden us to embark on new voyages.

Thinking in terms of safe harbors avoids the danger of inadvertently building ourselves a padded cell, which would prevent our critical participation in other spaces (Downey and Zhang 2015). A harbor is open to the world and free from the disciplinary constraints of the ivory tower. But all spaces—even those with sea views—restrict and limit as well as enable, so we should be wary of settling down on the harborside. Since it is central to STS to challenge dominant frames—to be "ontologically disobedient" (Woolgar 2005, 321)—we have a demolitionist streak. There will always be attempts to unsettle the foundations of any place for STS.

This reflects the fact that STS is a broad and heterogeneous academic collective, and not all of those who identify with it will choose to practice or endorse the approach that I have put forward here: one that incorporates observation of, collaboration with, and intervention into science and engineering. But my hope is that an articulation of this approach will be of use to embedded STS researchers who are attempting to find their ways in technoscientific worlds. By explicitly acknowledging these three different orientations as being part of STS research, we can recognize the value and limitations of each, the necessity of shifting between them in some circumstances, and the tensions that can result from doing so.

OBSERVATION, COLLABORATION, AND INTERVENTION

If we value itinerancy and "cultivate the art of crossing-over between lifeworlds" (Humphrey 2007, 23), then it becomes apparent that observation, collaboration, and intervention can all be appropriate methodological orientations at different times and in different places.

As an observer, an STS researcher can learn a great deal about a scientific field. One can take the position of an observer in any room. The laboratory in particular lends itself to an observational orientation—although such an orientation has its downsides in terms of the separation it can impose between the observer and the observed. In the lab, I attempted to observe the early-career scientists in a nonobjectifying manner with the same attentive care they applied to the yeast, to observe them in a way that was more than merely a detached scrutiny of the other. In the conference room, in contrast, such detached scrutiny is almost to be expected, and observation here does not give rise to methodological scruples because a conference is set up to be a show of sorts, where everyone is an observer in their turn.

In the art studio, adopting the position of an observer seemed inappropriate. This is one of the rooms in which I purposely shifted my orientation—from observer to collaborator—so that I could participate in a shared investigation of synthetic biology. In the policy room, I also described a shift, this time from intervener in the roadmapping process to observer of this process; although I would argue that my reflections on these observations (discussed in my paper with Claire Marris) were accompanied by a movement to a different room: the ivory tower. The ivory tower is a place for the type of observation that is retrospective. In fact, I am tempted to suggest that observation can only lead to otherwising with the addition of time. When one is in the midst of observation, whether caught up in the frenzy of the International Genetically Engineered Machine competition, absorbing a complex scientific lecture, or attempting to observe with attentive care, it is hard to step back and see how things could be different. But observation can be a foundation for otherwising when observation is in the mode of recollection (Pottage 2014).

Observation is free of the discomforts that often accompany collaboration and intervention. It allows for critical distance, and in some contexts, it can be the most suitable and productive orientation for an STS researcher. But in many rooms, I found the detachment that often accompanies observation methodologically and ethically problematic. Even in the laboratory, the scientists encouraged me to carry out a technical procedure, implying they found my observational positioning unsatisfactory. And the temporal detachment of retrospective observation in the ivory tower does not free one of the responsibilities and obligations to those whom one has observed.

Collaboration is my preferred mode of engaging with those synthetic biologists whom I interact with on a regular basis, many of whom have become my colleagues and epistemic partners. The coffee room and the art studio in particular provide opportunities for experimental collaborations that are not motivated by instrumental aims or tied to predefined deliverables but instead involve thinking *with* others. I value experimental collaborations highly because of their capacity to expand the imaginations of those involved and give rise to outcomes that are novel and unexpected. The collaborations in

Synthetic Aesthetics were transformative experiences for many of us, and they resulted in an emergent form of critique—something I would argue can only result from collaboration. Although collaboration carries with it the dangers of contamination and complicity—of identifying too strongly with the "we" of an interdisciplinary group—it provides valuable generative opportunities.

While thinking with others is key to collaboration, this is not the case for intervention, which may involve challenging or interrupting their activities. Intervention can take different forms. In the classroom, interventions could be described as "soft" (Fisher and Rip 2013)—unremarkable small-scale interactions that may increase reflexive awareness over time. The conference room provides opportunities for highly visible interventions from within the field, but the close proximity required for such interventions carries with it the danger of domestication. The policy room is another room in which one can choose to intervene, but with no guarantee of success, as my experiences show. One can intervene from outside synthetic biology from the bioethics building and, through writing, from the ivory tower. In these contexts, it is hard to predict the consequences of these interventions, and their effects may only be apparent in the long term.

Both collaboration and intervention might require getting one's hands dirty. And something the synthetic biologists in the lab and the biological artists in the art studio had in common was that they thought my hands were too clean because I was not directly manipulating biological entities. But my involvement in policy initiatives and in large research projects aiming to promote particular technical and market-oriented agendas makes my hands dirty in another sense.

The ivory tower may seem to be a place where one can wash one's hands, but this will only result in a semblance of cleanliness. As noted above, we cannot step away from our responsibilities and obligations to others in the ivory tower, a place that is itself laced with history and privilege. In fact, I do not think that interventionist and collaborative STS should be in the business of having clean hands. As Haraway (1997, 39) puts it, to be in the action is to be "finite and dirty, not transcendent and clean."

There is no free ride here (as Bijker 2003 notes), but that does not mean one has to travel alone. Acknowledging that collaboration and intervention as well as observation are legitimate methodological orientations in STS, sharing our experiences of them and the discomfort they often involve can, as I hope this book has shown, provide new insights and paths forward (see Horst 2013). This way of thinking also allows us to transcend the distinction between academic and activist forms of STS discussed in the introductory chapter. Instead of having to make a dichotomous choice, we have the freedom to move between the three orientations and the different opportunities they offer for otherwising.

Otherwising is my attempt to articulate a form of normativity that is authentic to and consistent with STS but rarely made explicit. It grows from STS work that attends to the contingency of scientific knowledge and practices, and in doing so, shows that they could be different. Otherwising is about what *could be* rather than what *ought to be*; it concerns the subjunctive and is potentially emancipatory. It provides an "opportunity, scope, or opening for something, by which it is rendered possible," to return to a definition of "room" from previous chapters. Otherwising can take place in any (physical) room, but the extent to which the range of imagined possibilities can be expanded is always context-dependent. In some situations, simply showing contingency where necessity is assumed can be a radical move. Although otherwising can be difficult, it is not something the STS researcher has to do alone. We can seek out and build relations with people who enable otherwising by seeing things in different ways, by opening up rather than closing down, by helping to keep doors wedged open.

SYNTHETIC BIOLOGY

I found these kinds of people in synthetic biology. When I first became involved in the field, they were trying to carve out a new space at the intersection of biology and engineering, challenging established disciplines and ways of working. They were often uncomfortable and liminal. Their vision sometimes seemed almost counter hegemonic, accompanied by talk of openness, democratization, and alternatives to the political economy of biotechnology. They were attempting to build a community that was fundamentally interdisciplinary, and they did not want social scientists to study them but to work with them to help create something new. Synthetic biologists became my epistemic partners, friends, and fellow travelers in this unconventional academic medley. At times, I felt more at home with synthetic biologists than with STS colleagues, and it is the synthetic biology conference posters that decorate the walls of my office.

Over the years, I have witnessed synthetic biology changing, becoming subsumed into more established fields such as industrial biotechnology and increasingly prioritizing commercialization over open access and democratization. Synthetic biology is now at the stage where to be attached to the field is most often to be attached to an agenda of industrialization and accessing the market.

For some synthetic biologists, industrialization and commercialization were always the overriding objectives. This is why they wanted the path of the technology to be cleared of potential ethical, legal, and social issues and why STS researchers who came with different agendas often did not fit with their expectations. This lack of fit is something I struggled with in many of the different rooms. Although my closest synthetic biology colleagues did gain a good understanding of my research interests, I think that much of my involvement in synthetic biology has been based on a misunderstanding of what it is that I can bring (which was one of my motivations for attempting to articulate it in these pages). It is also the case that STS researchers are not the only nonscientific group that engages with synthetic biology. Others such as lawyers, bioethicists, and science communication specialists may often better fulfill the expectations of scientists and engineers.

There seemed to be several good reasons, after spending a decade working in synthetic biology, to retreat to the ivory tower. This was only a temporary refuge, however, and my exit was not final. Riley (2019, 3), an STS researcher, describes her attempts to leave the field of engineering in terms of "a multiplicity of exits—geographic, institutional, disciplinary, relational, and epistemic," some of which "led back into engineering through circuitous paths." Other STS researchers even argue that "fieldwork turns out to be a more explicitly cyclical activity—one that is always more or less continuous" (Beaulieu 2010, 462). These observations show that we cannot necessarily control our future research trajectories, choosing what to study and when to leave. Almost all researchers have to be reactive to opportunities that arise, funding trends, theoretical developments, and pressing global concerns. Since liminality requires the relinquishing of certainty and control, we should perhaps embrace the indeterminacy of our future academic trajectories.

Another reason why my exit from synthetic biology was not final—why my "so long and thanks for all the fish" slide turned out not to be my swan song—was because I continue to encounter fresh opportunities for otherwising and experimental collaborations. But in my future work, I want to ensure that I am not tied into technocentric research and policy agendas. Such agendas were behind many of the scientific research programs I received funding from, and they drove the UK Synthetic Biology Roadmap. If the motivations behind these initiatives had been different—if they had been directed toward sustainability or global health, for example—this would have resulted in different kinds of interaction.

Many synthetic biologists I work with are open to conceiving of their research in other ways and are dissatisfied with the dominant framings of their field and its capture by industrial interests. I do think there is still scope to harness this dissatisfaction and use it to explore the breadth of options available, as I attempted to do in my talk at the SB7.0 conference.

Another form of critique that arises from within the field derives from the properties of biology itself, which often do not align with the instrumental goals of synthetic biology. As we saw in chapter 1, this results in a situation in which scientists and engineers are challenged to be open to the possibility of the living world. They have to come up with new ways of working *with* biology and its distinctive capacities. Since synthetic biology has the potential to bring novel living things into being (Koskinen 2017), it is conceivable that these new ways of working could lead to alternative trajectories and futures for biology that could diverge from those put forward by incumbents and elites. Such alternative biological futures could even give rise to new social and political possibilities. They would need to be created in collaboration with others, of course. Artists and designers are particularly well placed to imagine alternative futures and new ways of relating to living things. But we can find people who can expand our conception of the world in every room—from students to bioethicists to policymakers.

A PLACE FOR SCIENCE AND TECHNOLOGY STUDIES

In working with these diverse others, STS needs a safe harbor that is well stocked with useful resources to assist us in our interactions. What these resources should look like is the topic for a larger discussion that extends beyond this book, but I have some preliminary suggestions, drawn from all the previous chapters, which I hope will provide a starting point.

To begin an incomplete list, I think we need an articulation of the value and difficulty of otherwising, as well as a recognition of the time-consuming and emotional labor involved in moving between different locations, both physical and disciplinary. We need an awareness of the ongoing necessity to challenge expectations from others about the role of STS and an acknowledgment of the discomfort this often involves. All of this requires a collection of shared literature and experiences and a supply of (metaphorical) door wedges that we can use in every room we find ourselves in. Practically, we need a supportive community of peers and advisers and, ideally, a colleague with whom we can enter a new space. We also need to ensure we are involved from the earliest stages in interdisciplinary activities. Institutionally, we need commitments to support STS researchers who are between short-term contracts, as well as a recognition of the value of mixed and alternative publication outputs. At the funding level, we need mechanisms that allow us to build working relationships with scientists and engineers away from the demands of deliverables, combined with explicit support for experimental collaborations in which the outcomes will not be obvious from the outset. This may appear to be expecting too much of research funders, but some of these features were present in the sandpit, the grant-writing event that led to the Synthetic Aesthetics project.

Finally, having dedicated funding for independent STS research is crucial. A diversity of funding streams would allow us to embrace our liminality, to carry out work that is both engaged and autonomous, to participate in epistemic partnerships while simultaneously challenging entrenched interests.

A well-stocked safe harbor is a place that would allow for comings and goings, journeys to and from our fields of study. It would almost certainly have a nice library and a pub. It would provide a retreat and some protection, but since it would not be a disciplinary place, it would not have walls: it would not be a room.

This takes me back to the central metaphor that I have found useful throughout this book and shows its limitations. Thinking in terms of rooms sensitizes us to the constraints that we are working under and to the utility of adopting different strategies in different contexts. It demonstrates the power that comes from moving between rooms and seeing things afresh. It also allows us to make sense of the idea of exiting. But the walls of a room are constrictions that we may want to reject, particularly if we are attempting to create spaces for collaboration. And the most significant thing my experiences in synthetic biology have left me with is a commitment to the value of collaboration.

This resonates with an increasing recognition of the importance of collaboration in STS. Latour articulates this when reflecting on his work with climate scientists; he advocates a future "in which STS scholars are actively collaborating with those they study (whether these are scientists, lawyers, engineers, doctors, architects, or others) in building better worlds" (Mazanderani and Latour 2018, 300; see also Reardon 2013). Such collaborative world-building is likely to require the creation of new spaces.

NEW SPACES FOR COLLABORATION

This book has examined the possibilities and constraints of existing spaces, rather than exploring the creation of new ones, but I will end by sketching out three ideas for how we could start to conceptualize and build spaces for collaboration, which may provide directions for future work.

Most practically perhaps, these spaces could take the form of specially designed interdisciplinary workshops, configured to maximize emergent interactions and held in venues that encourage them, such as galleries, hackerspaces, or even parks. I have found that focused workshops on topics of shared concern can provide openings that are difficult to create in large science-dominated conference rooms or within the time-pressured and formal confines of the policy room. Attempting to create these kinds of spaces is always challenging, however. They can be taken over by powerful technical visions, and their outcomes can be elusive (see Smith et al. 2024). These difficulties are perhaps to be expected. Since these spaces are collaborative, STS researchers are likely to remain uncomfortable in them.

I have often found that the spaces that are most conducive for collaboration are ones that I have not actively been involved in designing. The coffee room is an obvious example here, but one that remains significant for me is Lake Clifton, an unexpected place of art/science/STS collaboration discussed in chapter 5. This was not a place for STS; it was a place where we were all out of place. Like the harbor, it had no walls; it was open and led on to other spaces. It was not clear what the frames were or how they could be challenged. But it provided room and took us out of our habitual ways of working and interacting. I would not advocate moving to Lake Clifton, but it may be useful to think of spending temporary periods of time with our collaborators in places like this.

The idea of a temporary location leads me to my final suggestion for thinking about new spaces for collaboration, making use of one last metaphor: the boat. A harbor is a place from which boats depart, and it can be useful to think of a collaboration as embarking on a voyage on a particular vessel.[1] This allows us to think about when we choose to board or not, the formalities of doing so, whether there is a choice of different boat, who influences the speed and destination of the vessel, and how and when we choose to disembark. Boats are more contained and defined than outdoor spaces. Their diversity also fits well with the many different types of collaboration: thinking in terms of luxury cruise liners, small sailing dinghies, utilitarian passenger ferries, icebreakers, and submarines, all give rise to intriguing possibilities. Furthermore, boats have a particular relationship with space. As Michel Foucault (1986, 27) puts it: “The boat is a floating piece of space, a place without a place, that exists by itself, that is closed in on itself and at the same time is given over to the infinity of the sea.”[2] Collaborations, particularly experimental collaborations, are similarly contained and limited, in the sense that they are focused on particular relationships. But they have almost boundless potential.

Whether we think in terms of boats, outdoor spaces, or bespoke workshops, whether we help build new spaces or work within existing ones, my final thought is that we should embrace the opportunities provided by collaboration, despite its inevitable discomforts. At its best, collaboration can tug at unrealized potentialities and reveal the constraints of the present, opening up possibilities and bringing alternatives to light. Such collaborative work is necessarily risky, but it is also hopeful.

NOTES

INTRODUCTION

1. UK figures are quoted above. The Wilson Center (2015, 3) reports that "between 2008 and 2014, the United States invested a total of $820 million . . . in synthetic biology research."

2. Personal communication, Barend van der Meulen, February 6, 2013.

3. Agnew (2011) and Cresswell (2014) formulate this slightly differently as location, locale, and sense of place.

4. Throughout this book, when I draw on dictionaries or etymology, it is not to put forward an authoritative or "correct" definition of a word; it is because I find that these sources can remind us of, or draw attention to, aspects of a word that might otherwise be overlooked, which can sometimes be illuminating.

5. A brief exception is when I discuss a period of enforced domesticity in the ivory tower (chapter 8).

6. See, for example, O'Malley et al. (2008), Calvert (2010), Schyfter and Calvert (2015), and Calvert and Szymanski (2020).

7. I draw inspiration from Rabinow and Bennett (2012), who are similarly reflexive about their engagements in synthetic biology, but because they do not identify as STS researchers, they do not share my overriding concern with the place and future of STS.

CHAPTER 1

1. The miniprep happens to be a variant of the plasmid prep, discussed in a classic paper by sociologists of science Jordan and Lynch (1992), who explore the diversity of ways in which the technique can be carried out.

2. Their attempts to engineer and control the yeast, however, often resulted in its destruction (see Calvert and Szymanski 2020 on these seemingly contradictory relationships to the organism).

3. This term is often used by scientists to describe themselves when they are being studied by social scientists.

CHAPTER 2

1. See "SynBERC (synthetic biology research center)," https://ebrc.org/synberc/.

2. Egenis, the ESRC Centre for Genomics and Society, was funded by the UK's Economic and Social Research Council from 2002 to 2012 and led by Professor John Dupré. It continues to operate at the time of writing as the Centre for the Study of the Life Sciences (http://socialsciences.exeter.ac.uk/sociology/research/sts/egenis/).

3. See "Synthetic Biology: Synthetic Biology 1.0/Videos," First International Meeting on Synthetic Biology, MIT, Cambridge, MA, June 10–12, 2004, https://openwetware.org/wiki/Synthetic_Biology:Synthetic_Biology_1.0/Videos.

4. Drew Endy in SB4.0 field notes.

5. Drew Endy in SB4.0 field notes.

6. The full title of the ETC Group is Action Group on Erosion, Technology, and Concentration (https://etcgroup.org).

7. Pat Mooney in SB4.0 field notes.

8. The presentations were given by Eleonore Pauwels (Woodrow Wilson Center) and Megan Palmer (Stanford University).

9. Paulo Paes de Andrade in SB6.0 field notes.

10. Maria Mercedes Roca in SB6.0 field notes.

11. Luddites200, "Open letter to synthetic biologists," July 10, 2013, https://web.archive.org/web/20131215130014/http://luddites200blog.org.uk/2013/07/open-letter-to-synthetic-biologists/.

12. See "SB7.0," 7th International Meeting on Synthetic Biology, National University of Singapore, June 13–16, 2017, https://openwetware.org/wiki/SB7.0.

13. As chapter 5 on the art studio describes, three of us had previously worked together.

14. The only nonscientific sessions at a SEED conference at the time of writing in 2019 were a "funders panel" and an "entrepreneurship panel."

15. At the time of writing, the tagline is "Biotechnology in the public interest."

16. I am grateful to Eunjeong Ma for making this observation at the workshop on "Collaboration between Social Sciences and Engineering," Daejeon, South Korea, February 19, 2014.

17. To add another layer of irony, this had inadvertently been an appropriate choice on my part. Wile E. Coyote aspires to be a cunning trickster, but he is never successful at catching the Road Runner, and his efforts to achieve his aims almost always backfire. He is often depicted trying in vain to protect himself from a huge falling boulder with a small umbrella.

CHAPTER 3

1. It is not a coincidence that like the brand "iPhone," iGEM is always written with a small "i"—which aspires to evoke the foundational technological advances underlying Apple's device as well as the creative and technological potential of synthetic biology (Bennett et al. 2009; Endy and Lazowska 2008; Matheson 2017).

2. See iGEM, "Team list for iGEM 2019 championship," https://old.igem.org/Team_List?year=2019&name=Championship&division=igem. The 2019 competition was the last in-person Jamboree at the time of writing.

3. The Registry of Standard Biological Parts is online at http://parts.igem.org/.

4. Rettberg in iGEM 2011 field notes.

5. From 2010 to 2013, the competition was divided into regional heats, with the final Jamboree being held at MIT.

6. Rettberg in iGEM 2016 field notes.

7. Rettberg in iGEM 2009 and 2010 field notes.

8. See iGEM, "Team: ArtScience Bangalore/Our Approach," 2009, http://2009.igem.org/Team:ArtScienceBangalore/Aproach.

9. This image was of Raj Kapoor and Nargis from the 1955 movie *Shree 420*.

10. iGEM 2009 closing ceremony field notes.

11. iGEM, "Team: ArtScience Bangalore/Our Approach."

12. This is also reflected in their references to artists such as Tuur van Balen, Joe Davis, and Adam Zaretsky in their wiki.

13. See iGEM, "Human Practices beyond the competition," 2019, https://2019.igem.org/Human_Practices/History.

14. iGEM, "Introduction: What is Human Practices," 2019, https://2019.igem.org/Human_Practices/Introduction.

15. iGEM, "How to succeed with Human Practices," 2019, https://2019.igem.org/Human_Practices/How_to_Succeed.

16. iGEM, "Human Practices beyond the competition."

17. iGEM, "Ethics: Overview," 2009, http://2009.igem.org/Team:Paris/Ethics_overview#top.

18. An attempt to address these differences was made in 2015, when the Human Practices special prize was separated into two distinct prizes: "Best Integrated Human Practices" and "Best Education & Public Engagement" (see iGEM, "Human Practices beyond the competition").

19. Hallinan et al. (2019, 29) argue that their 2010 iGEM project "was key in strengthening interdisciplinary links at Newcastle University." The collaborations on which this project was based have since led to an £8 million research center, the Hub for Biotechnology in the Built Environment (http://bbe.ac.uk).

20. This term is sometimes used by synthetic biologists to refer to supervising iGEM students (Frow and Calvert 2013b).

21. Frow (2020, 1053) argues that the dominance of the deficit model in bioscience communities in the UK owes much to experiences with genetically modified crops in the 1990s, which led to publics being "framed as an obstacle to the delivery of social benefits through science."

22. The course's specialist focus and master's-level intake distinguish it from large undergraduate science and society courses, however.

23. At the time of writing, plans are that future iGEM competitions will have a greater emphasis on sustainability (Fong 2020).

CHAPTER 4

1. Pubs and coffee shops, along with public libraries, bookshops, and barbershops, are described by Oldenburg (1999) as "third places"—places for informal interaction that are neither home nor workplace.

2. Science happened in the pub, too—see, for example, Secord 1994.

3. Habermas's notion of the "public sphere" has similarities with Oldenburg's (1999) concept of the "third place," although Habermas emphasizes the political importance of these places while Oldenburg stresses their recreational function (Fong 2017).

4. Early coffeehouses were notable for their exclusion of women, however (Thompson 1993).

5. Pubs and coffee rooms can, of course, be used for this purpose on certain occasions—for example, by hosting a Cafe Scientifique (http://cafescientifique.org/).

6. Collingridge's (1980) dilemma is discussed further in chapter 6 on the bioethics building.

7. For a while, a prominent synthetic biologist used "for infidel heteroglossia!" as an email sign-off, alluding to Haraway's (1985) "Cyborg Manifesto".

8. This is the topic of commensality—the sociological study of eating together (Shapin 2020).

9. A situation that is reversed in the classroom, as discussed in the previous chapter.

CHAPTER 5

1. Stromatolites are microbial structures that are more ancient and more widespread than thrombolites; see Kennard and James (1986).

2. It was the easy-listening vibraphone music that accompanied “The Gallery” as part of *Take Hart*, a British children’s TV program from the 1970s and 1980s.

3. See “SymbioticA,” University of Western Australia, http://www.symbiotica.uwa.edu.au/.

4. See Mediamatic, https://www.mediamatic.net/.

5. All the US-based residences were covered by Pablo Schyfter.

6. This description is taken from the SymbioticA website (http://www.symbiotica.uwa.edu.au/).

7. In this project, a collaboration with Ionat Zurr and Guy Ben Ary, bone marrow stem cells from pigs were grown in the shape of wings. See “Pigs Wings,” The Tissue Culture & Art Project, 2000–2001, https://tcaproject.net/portfolio/pigs-wings/.

8. The lake’s full name is Noorook Yalgorup-Lake Clifton. The local Indigenous Binjareb Noongar people describe the thrombolites as the eggs of the Waugal, “the creation snake which is giver of all life” (Gobby, Merewether, and Nykiel 2021, 226).

9. See “About Mediamatic,” https://www.mediamatic.net/en/page/10341/this-is-mediamatic.

10. Protocell creation coexists alongside the parts-based and whole genome engineering approaches to synthetic biology described in chapter 1 (O’Malley et al. 2008).

11. There has been a recent burgeoning of literature that explores the connections between STS and art and design (see, e.g., Borgdorff, Peters, and Pinch 2019; Sormani, Carbone, and Gisler 2019; Rogers et al. 2021).

12. For further information, see “Synthetic Biology Leadership Council,” Innovate UK KTN, https://www.ktn-uk.co.uk/programme/synthetic-biology-leadership-council.

13. Such internal critique was also apparent in the reaction to the Intrexon talk at the SB7.0 meeting, as described in chapter 2, on the conference room.

CHAPTER 6

1. This may be because in the original ELSI program attached to the Human Genome Project in the 1990s, ethics claimed the largest share of the funds, creating “the world’s largest bioethics program” (Franklin 2019, 629).

2. The other horn of the dilemma is that in the later stages of the development of a technology, while its trajectory is much clearer, the power to control its development is far more limited.

3. An external evaluation of the Nuffield Council's work in 2006 recommended the use of an ethical framework—"a set of ethical principles capable of being applied consistently and designed to guide our response to a particular problem or set of problems" (Chan and Harris 2006, 7)—in all its reports.

4. Joan Fujimura first made me aware of this phrase, attributing it to her supervisor Anselm Strauss.

5. Personal communication, Jim Dratwa, head of the European Group on Ethics in Science and New Technologies, July 27, 2018.

CHAPTER 7

1. As noted previously, it was the subtitle of this paper that inspired me to start thinking about rooms for STS.

2. See the Biotechnology and Biological Sciences Research Council Order 1994, https://www.legislation.gov.uk/uksi/1994/423/made?view=plain.

3. See UK Research and Innovation, "Strategy advisory panels," last updated June 24, 2022, https://bbsrc.ukri.org/about/governance-structure/panels/.

4. See BBSRC, "Bioscience for Society Strategy Advisory Panel," last updated 2017, https://web.archive.org/web/20171210094759/http://www.bbsrc.ac.uk/about/governance-structure/panels/society/.

5. The debate concluded that there was little support for the early commercialization of GM crops (see Irwin 2008).

6. BBSRC, "Bioscience for Society Strategy Advisory Panel."

7. Sadly, this report is no longer online.

8. At the time of writing, there were no social scientists on the BBSRC council; see UK Research and Innovation, "BBSRC council," last updated November 14, 2022, https://bbsrc.ukri.org/about/governance-structure/council/.

9. BBSRC, "Research spend by institution type," undated, https://web.archive.org/web/20210117162637/https://bbsrc.ukri.org/about/spending/research-spend-institution/.

10. The deficit model is discussed in chapter 3, on the classroom.

11. This resonates with the recommendations made in a paper coauthored by academics and BBSRC officials that was first drafted during the same period (see Smith et al. 2021).

12. Meeting papers, January 26, 2015.

13. Meeting minutes, July 12, 2016.

14. Meeting papers, March 5, 2018.

15. UK Research and Innovation (UKRI), which brought together the activities of the seven research councils, was established on April 1, 2018.

16. It was later renamed the Department for Business, Energy, and Industrial Strategy.

17. See the Great Campaign website, https://www.greatcampaign.com/.

18. Like Zuiderent-Jerak (2016), I was attempting to harness the criticisms of a practice that come from within that practice.

19. This quote is from the text of the Synthetic Aesthetics project team's open letter responding to the *Biodesign for the Bioeconomy* report (SBLC 2016a), described in chapter 5, on the art studio.

20. Owen and Pansera (2019, 26) distinguish RRI, "a policy-driven discourse that emerged from the European Commission," from responsible innovation (RI), "which has in contrast emerged largely from academic roots." In synthetic biology policy contexts, however, these terms are used interchangeably, so I do not make this distinction here.

21. As discussed in Martin (1996), for example.

22. Despite the differences in terminology, Zuiderent-Jerak's experimental intervention has many similarities to experimental collaboration as I have described it in previous chapters, because it "does not operate from a detached scholarly position, nor does it aim at implementing a pre-set normative agenda" (Zuiderent-Jerak 2015, 5). Instead, normative concerns arise out of the particular context being studied.

CHAPTER 8

1. Or a place of imprisonment, as it was for Rapunzel.

2. Personal communication, Robin Williams, October 3, 2018.

3. As noted in the preface, this was the European Research Council (ERC) project named Engineering Life (grant number 616510).

4. A famous literary example that makes this point is Proust's withdrawal to his cork-lined bedroom to write *In Search of Lost Time* (1871–1922).

CONCLUSIONS

1. This idea originates from Claire Marris, personal communication, December 5, 2012.

2. Foucault (1986) makes this comment in his essay "Of other spaces," which discusses heterotopias—places that contain within them seemingly contradictory elements.

REFERENCES

Agnew, J. 2011. Space and place. In *Handbook of Geographical Knowledge*, edited by J. Agnew and D. Livingstone, 316–330. London: Sage.

Aguiton, S. 2011. Defining the agenda. Presentation at the Synthetic Biology and the Social Sciences Seminar Series, Genomics Forum, Edinburgh, February 14–15.

Andrianantoandro, E., S. Basu, D. Karig, and R. Weiss. 2006. Synthetic biology: New engineering rules for an emerging discipline. *Molecular Systems Biology* 2 (1): 2006.0028. https://doi.org/10.1038/msb4100073.

Anonymous. 2015. Queer adventures in synthetic biology: The detournement of the comic. *Freed the Drosophilias!* April 18. https://freedthedrosophilias.noblogs.org/post/2015/04/18/queer-adventures-in-synthetic-biology-the-detournement-of-the-comic.

Ashmore, M., G. Myers, and J. Potter. 1994. Seven days in the library: Discourse, rhetoric, reflexivity. In *Handbook of Science, Technology, and Society*, edited by S. Jasanoff, G. Markle, J. Petersen, and T. Pinch, 321–342. London: Sage.

Atkinson, P., and M. Hammersley. 1998. Ethnography and participant observation. In *Strategies of Qualitative Inquiry*, edited by N. Denzin and Y. Lincoln, 248–261. Thousand Oaks, CA: Sage.

Ball, P. 2014. Synthetic aesthetics: Challenging science fictions. *Chemistry World*, June 27. https://www.chemistryworld.com/culture/synthetic-aesthetics/7504.article.

Balmer, A., and K. Bulpin. 2013. Left to their own devices: Post-ELSI, ethical equipment and the International Genetically Engineered Machine (iGEM) Competition. *BioSocieties* 8:311–335.

Balmer, A., K. Bulpin, and S. Molyneux-Hodgson. 2016. *Synthetic Biology: A Sociology of Changing Practices*. Basingstoke: Palgrave Macmillan.

Balmer, A., J. Calvert, C. Marris, S. Molyneux-Hodgson, E. Frow, M. Kearnes, K. Bulpin, P. Schyfter, A. Mackenzie, and P. Martin. 2015. Taking roles in interdisciplinary collaborations: Reflections on working in post-ELSI spaces in the UK synthetic biology community. *Science and Technology Studies* 28 (3): 3–25.

Barben, D., E. Fisher, C. Selin, and D. Guston. 2008. Anticipatory governance of nanotechnology: Foresight, engagement, and integration. In *Handbook of Science and Technology Studies*, 3rd ed., edited by E. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman, 979–1000. Cambridge, MA: MIT Press.

Barry, A., G. Born, and G. Weszkalnys. 2008. Logics of interdisciplinarity. *Economy and Society* 37 (1): 20–49.

BBSRC. 2004. *Biotechnology and Biological Sciences Research Council Annual Report and Accounts 2003–2004*. London: The Stationery Office.

Bea, S. 2017. *No Heroics, Please: Mapping Deceased Donation Practices in a Catalan Hospital*. PhD diss., University of Edinburgh.

Beaulieu, A. 2010. Research note: From co-location to co-presence: Shifts in the use of ethnography for the study of knowledge. *Social Studies of Science* 40:453–470.

Beaulieu, A., A. Scharnhorst, and P. Wouters. 2007. Not another case study: Ethnography, formalisation and the scope of science. *Science, Technology & Human Values* 32 (6): 672–692.

Benda, L. 2012. To bridge the gap between the two cultures: A social pre-history of the strong program in the sociology of knowledge. In *Scientific Cosmopolitanism and Local Cultures: Religions, Ideologies, Societies: Proceedings of the 5th International Conference of the European Society for the History of Science*, 705–771. Athens: National Hellenic Research Foundation.

Benner, S. 2010. Q&A: Life, synthetic biology and risk. *BMC Biology* 8 (1): 77.

Bennett, G., N. Gilman, A. Stavrianakis, and P. Rabinow. 2009. From synthetic biology to biohacking: Are we prepared? *Nature Biotechnology* 27 (12): 1109–1111.

Bernstein, M., K. Reifschneider, I. Bennett, and J. Wetmore. 2017. Science outside the lab: Helping graduate students in science and engineering understand the complexities of science policy. *Science and Engineering Ethics* 23 (3): 861–882.

Berry, H. 2005. Review: The coffee house: A cultural history, by Markman Ellis. *English Historical Review* 120 (489): 1447–1448.

Bijker, W. 1997. *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA: MIT Press.

Bijker, W. 2003. The need for public intellectuals: A space for STS. *Science, Technology & Human Values* 28 (4): 443–450.

BioBricks Foundation. 2011. *SB5.0: The Fifth International Meeting on Synthetic Biology*. Conference program, Stanford, CA, June 15–17. https://web.archive.org/web/20110626062343/http://sb5.biobricks.org/files/sb5-program-book-v3.pdf.

Bloor, D. 2003. Obituary: David Owen Edge. *Social Studies of Science* 33 (2): 171–176.

Borgdorff, H., P. Peters, and T. Pinch. 2019. *Dialogues between Artistic Research and Science and Technology Studies*. London: Routledge.

Born, G., and A. Barry. 2010. Art-science: From public understanding to public experiment. *Journal of Cultural Economy* 3 (1): 103–119.

Boudry, M., and M. Pigliucci. 2013. The mismeasure of machine: Synthetic biology and the trouble with engineering metaphors. *Studies in the History and Philosophy of the Biological and Biomedical Sciences* 44 (4 Pt B): 660–668.

Breithaupt, H. 2006. The engineer's approach to biology. *EMBO Reports* 7:21–24.

Brent, R. 2004. A partnership between biology and engineering. *Nature Biotechnology* 22 (10): 1211–1214.

Bristow, A. 2012. On life, death and radical critique: A non-survival guide to the Brave New Higher Education for the intellectually pregnant. *Scandinavian Journal of Management* 28:234–241.

Callahan, D. 2012. *The Roots of Bioethics: Health, Progress, Technology, Death*. Oxford: Oxford University Press.

Callard, F., and D. Fitzgerald. 2015. *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences*. Basingstoke: Palgrave Macmillan.

Callon, M. 1994. Is science a public good? *Science, Technology & Human Values* 19 (4): 395–424.

Callon, M., P. Lascoumes, and Y. Barthe, 2009. *Acting in an Uncertain World: An Essay on Technical Democracy*. Translated by Graham Burchell. Cambridge, MA: MIT Press.

Calvert, J. 2010. Synthetic biology: Constructing nature? *Sociological Review* 58 (S1): 95–112.

Calvert, J., and E. Szymanski. 2020. A feeling for the (micro)organism? Yeastiness, organism agnosticism and whole genome synthesis. *New Genetics and Society* 39 (4): 385–403.

Cameron, D., C. Bashor, and J. Collins. 2014. A brief history of synthetic biology. *Nature Reviews Microbiology* 12:381–390.

Campos, L. 2009. That was the synthetic biology that was. In *Synthetic Biology: The Technoscience and its Societal Consequences*, edited by M. Schmidt, A. Kelle, A. Ganguli-Mitra, and H. de Vriend, 5–21. Heidelberg: Springer.

Campos, L. 2013. Outsiders and in-laws: Drew Endy and the case of synthetic biology. In *Outsider Scientists: Routes to Innovation in Biology*, edited by O. Harman and M. Dietrich, 331–348. Chicago: University of Chicago Press.

Calhoun, B. 2012. Shaping the public sphere: English coffeehouses and French salons and the Age of the Enlightenment. *Colgate Academic Review* 3 (7): 75–99.

Canguilhem, G. 2008. *Knowledge of Life*. New York: Fordham University Press.

Carlson, R. 2010. *Biology Is Technology: The Promise, Peril, and New Business of Engineering Life*. Cambridge, MA: Harvard University Press.

Carlson, R. 2011. It is the end of the world as we know it, and I feel strangely ambivalent: Synthetic Biology 5.0. *Synthesis Blog*, June 27. http://rob-carlson-94m2.squarespace.com/synthesis/?offset=1310994539000.

Carrigan, M. 2015. Life in the accelerated academy: Anxiety thrives, demands intensify and metrics hold the tangled web together. *LSE Impact Blog*, April 7. http://blogs.lse.ac.uk/impactofsocialsciences/2015/04/07/life-in-the-accelerated-academy-carrigan/.

Carrithers, M. 2005. Anthropology as a moral science of possibilities. *Current Anthropology* 46 (3): 433–456.

Casey, E. 2001. Between geography and philosophy: What does it mean to be in the place-world? *Annals of the Association of American Geographers* 91:683–693.

Catts, O. 2016. SynBio recreating society. Presentation at Synenergene Forum, Amsterdam, Netherlands, June 24–25, 2016.

Catts, O. 2018. Introductory comments. What can art, STS and synthetic biology do together? Workshop at the Institute of Advanced Studies, University of Western Australia, October 22 2018.

Catts, O., and G. Cass. 2008. Labs shut open: A biotech hands-on workshop for artists. In *Tactical Biopolitics: Art, Activism, and Technoscience*, edited by B. da Costa and K. Philip, 143–156. Cambridge, MA: MIT Press.

Catts, O., and I. Zurr. 2008. The ethics of experiential engagement with the manipulation of life. In *Tactical Biopolitics: Art, Activism, and Technoscience*, edited by B. da Costa and K. Philip, 125–142. Cambridge, MA: MIT Press.

Catts, O., and I. Zurr. 2014. Countering the engineering mindset: The conflict of art and synthetic biology. In *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*, edited by A. D. Ginsberg, J. Calvert, P. Schyfter, A. Elfick, and D. Endy, 27–37. Cambridge, MA: MIT Press.

Catts, O., and I. Zurr. 2018. Artists working with life (sciences) in contestable settings. *Interdisciplinary Science Reviews* 43 (1): 40–53.

Cello, J., A. Paul, and E. Wimmer. 2002. Chemical synthesis of poliovirus cDNA: Generation of infectious virus in the absence of natural template. *Science* 297 (5583): 1016–1018.

Chan, S., and J. Harris. 2006. *The Nuffield Council on Bioethics: An Ethical Review of Publications*. London: Nuffield Council on Bioethics.

Chang, H. 2012. *Is Water H_2O? Evidence, Realism and Pluralism*. Dordrecht: Springer.

Chedd, G. 1971. Danielli the prophet. *New Scientist and Science Journal* (January 21): 124–125.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Clarke, L., and R. Kitney. 2016. Synthetic biology in the UK: An outline of plans and progress. *Synthetic and Systems Biotechnology* 1:243–257.

Cockerton, C. 2011. *Going Synthetic: How Scientists and Engineers Imagine and Build a New Biology*. PhD diss., London School of Economics and Political Science.

Collingridge, D. 1980. *The Social Control of Technology*. London: Frances Pinter.

Cool, A., B. Cakici, and N. Seaver. 2017. Making sense of conferences. Session at the Society for the Social Studies of Science, Boston, August 30–September 2.

https://convention2.allacademic.com/one/ssss/ssss17/index.php?cmd=Online+Program+View+Session&selected_session_id=1285998&PHPSESSID=8urdglha8lu04mp4j4jt9d5621.

Corbera, E., I. Anguelovski, J. Honey-Rosés, and I. Ruiz-Mallén. 2020. Academia in the time of COVID-19: Towards an ethics of care. *Planning Theory & Practice* 21 (2): 191–199.

Cresswell, T. 2014. Place. In *The SAGE Handbook of Human Geography*, edited by R. Lee, N. Castree, R. Kitchin, V. Lawson, A. Paasi, C. Philo, S. Radcliffe, S. Roberts, and C. Withers, 7–25. London: Sage.

Croissant, J. 1999. The view from the basement: The ethics and politics of teaching engineers while studying them. *Anthropology of Work Review* 20 (1): 22–27.

Davies, G. 2011. Playing dice with mice: Building experimental futures in Singapore. *New Genetics and Society* 30 (4): 433–441.

Derrida, J. 1983. The principle of reason: The university in the eyes of its pupils. *Diacritics* 13 (3): 2–20.

de Saille, S. 2015. Innovating innovation policy: The emergence of "responsible research and innovation." *Journal of Responsible Innovation* 2 (2): 152–168.

de Saille, S., and F. Medvecky. 2016. Innovation for a steady state: A case for responsible stagnation. *Economy and Society* 45 (1): 1–23.

Dixon, D. 2009. Creating the semi-living: On politics, aesthetics and the more-than-human. *Transactions of the Institute of British Geographers* 34:411–425.

Doing, P. 2008. Give me a laboratory and I will raise a discipline: The past, present, and future politics of laboratory studies in STS. In *Handbook of Science and Technology Studies*, 3rd ed., edited by E. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman, 279–295. Cambridge, MA: MIT Press.

Downey, G., and J. Dumit. 1997. Locating and intervening: An introduction. In *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, edited by G. Downey and J. Dumit, 5–29. Santa Fe, NM: School of American Research Press.

Downey, G., and Z. Zhang. 2015. Nonlinear STS, engineering studies, and dominant images of engineering formation: An interview with Professor Gary Downey. *STS Infrastructures: Platform for Experimental Collaborative Ethnography*. https://stsinfrastructures.org/sites/default/files/artifacts/media/pdf/downeyzhang_nonlinearsts_interview_20151.pdf.

Dunne, A., and F. Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge, MA: MIT Press.

Dymond, J., and J. Boeke. 2012. The Saccharomyces cerevisiae SCRaMbLE system and genome minimization. *Bioengineering Bugs* 3 (3): 168–171.

Elfick, A., and D. Endy. 2014. Synthetic biology: What it is and why it matters. In *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*, edited by A. D. Ginsberg, J. Calvert, P. Schyfter, A. Elfick, and D. Endy, 3–25. Cambridge, MA: MIT Press.

Emergence Newsletter. 2007. Synthetic Biology 3.0 in Zurich, June 24–26. Newsletter #1, July. http://www.emergence.ethz.ch/Newsletter/newsletter.htm.

Endy, D. 2005. Foundations for engineering biology. *Nature* 438 (November 24): 449–453.

Endy, D. 2008. Synthetic biology: Can we make biology easy to engineer? *Industrial Biotechnology* 4 (4): 340–351.

Endy, D., and E. Lazowska. 2008. The imperative of synthetic biology: A proposed national research initiative. White paper prepared for the Computing Community Consortium, committee of the Computing Research Association, December 12. https://cra.org/ccc/wp-content/uploads/sites/2/2015/05/Synthetic_Biology.pdf.

EPSRC. 2013. Framework for responsible innovation, October 10. https://web.archive.org/web/20131010122828/http://www.epsrc.ac.uk/research/framework/Pages/framework.aspx.

Estalella, A., and T. Sanchez-Criado. 2015. Experimental collaborations: An invocation for the redistribution of social research. *Convergence: The International Journal of Research into New Media Technologies* 21 (3): 301–305.

ETC Group. 2006. Global coalition sounds the alarm on synthetic biology, demands oversight and societal debate. News release, May 18. https://www.etcgroup.org/content/global-coalition-sounds-alarm-synthetic-biology.

Eyben, R. 2009. Hovering on the threshold: Challenges and opportunities for critical and reflexive ethnographic research in support of international aid practice. In *Ethnographic Practice and Public Aid: Methods and Meanings in Development Cooperation*, edited by C. Widmark and S. Hagberg, 71–98. Uppsala: University of Uppsala.

Farías, I., and A. Wilkie. 2015. Studio studies: Notes for a research program. In *Studio Studies: Operations, Topologies & Displacements*, edited by I. Farías and A. Wilkie, 1–21. New York: Routledge.

Farny, N. 2018. A vision for teaching the values of synthetic biology. *Trends in Biotechnology* 36 (11): 1097–1100.

Felt, U. 2009. *Knowing and Living in Academic Research: Convergence and Heterogeneity in Research Cultures in the European Context*. Prague: Academy of Sciences of the Czech Republic.

Felt, U. 2014. Within, across and beyond: Reconsidering the role of social sciences and humanities in Europe. *Science as Culture* 23 (3): 384–396.

Felt, U. 2017. Under the shadow of time: Where indicators and academic values meet. *Engaging Science, Technology, and Society* 3:53–63.

Felt, U. 2018. Responsible research and innovation. In *Routledge Handbook of Genomics, Health and Society*, edited by S. Gibbon, B. Prainsack, S. Hilgartner, and J. Lamoreaux, 108–116. Abingdon: Routledge.

Felt, U., R. Fouché, C. Miller, and L. Smith-Doerr. 2017. *Handbook of Science and Technology Studies*, 4th ed. Cambridge, MA: MIT Press.

Fisher, E. 2005. Lessons learned from the ethical, legal and social implications program (ELSI): Planning societal implications research for the National Nanotechnology Program. *Technology in Society* 27:321–328.

Fisher, E., C. Mitcham, and R. Mahajan. 2006. Midstream modulation of technology: Governance from within. *Bulletin of Science, Technology & Society* 26: 485–496.

Fisher, E., and A. Rip. 2013. Responsible innovation: Multi-level dynamics and soft intervention practices. In *Responsible Innovation*, edited by R. Owen, J. Bessant, and M. Heinz, 165–183. London: John Wiley & Sons.

Fitzgerald, D., and F. Callard. 2014. Social science and neuroscience beyond interdisciplinarity: Experimental entanglements. *Theory Culture Society* 3 (1): 3–32.

Fong, C. 2020. iGEM meets Just One Giant Lab on the road to a sustainable future. *Makery*, July 23. https://www.makery.info/en/2020/07/23/english-igem-meets-just-one-giant-lab-on-the-road-to-a-sustainable-future/.

Fong, J. 2017. *The Death Café Movement: Exploring the Horizons of Mortality*. Cham: Palgrave Macmillan.

Forsythe, D. E. 1999. Ethics and politics of studying up in technoscience. *Anthropology of Work Review* 20:6–11.

Fortun, M. 2005. For an ethics of promising, or: A few kind words about James Watson. *New Genetics and Society* 24 (2): 157–174.

Foucault, M. 1986. Of other spaces. *Diacritics* 16 (1): 22–27.

Franklin, S. 2019. Ethical research: The long and bumpy road from shirked to shared. *Nature* 574 (October 31): 627–630.

Fraser, M. 2006. The ethics of reality and virtual reality. *History of the Human Sciences* 19 (20): 45–72.

Freeth, R. 2019. *Formative Accompanying Research with Collaborative Interdisciplinary Teams*. PhD diss., Leuphana University, Lüneburg.

Frow, E. 2013. Making big promises come true? Articulating and realizing value in synthetic biology. *BioSocieties* 8:432–448.

Frow, E. 2015. Designing reflection at the iGEM Jamboree. *Engineering Life Blog*, November 2. https://blogs.sps.ed.ac.uk/engineering-life/2015/11/02/designing-reflection-at-the-igem-jamboree/.

Frow, E. 2020. From "experiments of concern" to "groups of concern": Constructing and containing citizens in synthetic biology. *Science, Technology & Human Values* 45 (6): 1038–1064.

Frow, E., and J. Calvert. 2013a. "Can simple biological systems be built from standardized interchangeable parts?" Negotiating biology and engineering in a synthetic biology competition. *Engineering Studies* 5 (1): 42–58.

Frow, E., and J. Calvert. 2013b. Opening up the future(s) of synthetic biology. *Futures* 48:32–43.

Gallardo, C. 2019. Doubts over evidence for synthetic biology plan. *Research Professional*, February 27. https://www.researchprofessionalnews.com/rr-news-uk-politics-2019-2-doubts-over-evidence-for-synthetic-biology-plan/.

Garforth, L. 2012. In/visibilities of research: Seeing and knowing in STS. *Science, Technology & Human Values* 37:264–285.

Garforth, L., and A. Cervinková. 2009. Times and trajectories in academic knowledge production. In *Knowing and Living in Academic Research: Convergence and Heterogeneity in Research Cultures in the European Context*, edited by U. Felt, 169–226. Prague: Academy of Sciences of the Czech Republic.

Gibson, D. G., G. A. Benders, C. Andrews-Pfannkoch, E. A. Denisova, H. Baden-Tillson, J. Zaveri, T. B. Stockwell et al. 2008. Complete chemical synthesis, assembly, and cloning of a mycoplasma genitalium genome. *Science* 319 (5867): 1215–1220.

Gieryn, T. 2000. A space for place in sociology. *Annual Review of Sociology* 26 (1): 463–496.

Gieryn, T. 2006. City as truth-spot: Laboratories and field-sites in urban studies. *Social Studies of Science* 36 (1): 5–38.

Ginsberg, A. 2018. *Better: Navigating Imaginaries in Design and Synthetic Biology to Question "Better."* PhD diss., Royal College of Art, London.

Ginsberg, A. D., J. Calvert, P. Schyfter, A. Elfick, and D. Endy. 2014. *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*. Cambridge, MA: MIT Press.

Gobby, B., J. Merewether, and A. Nykiel. 2021. Extinction, education and the curious practice of visiting thrombolites. *Environmental Education Research* 27 (2): 217–233.

González-Santos, S., and R. Dimond. 2015. Medical and scientific conferences as sites of sociological interest: A review of the field. *Sociology Compass* 9 (3): 235–245.

Gregory, J., and S. Miller. 1998. *Science in Public: Communication, Culture, and Credibility*. Cambridge, MA: Perseus Publishing.

Gusterson, H. 1997. Studying up revisited. *PoLAR: Political and Legal Anthropology Review* 20 (1): 114–119.

Habermas, J. 1989. *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society*. Cambridge, MA: MIT Press.

Hackett, E., O. Amsterdamska, M. Lynch, and J. Wajcman. 2008. *Handbook of Science and Technology Studies*, 3rd ed. Cambridge, MA: MIT Press.

Hagen, K. 2016. Science policy and concomitant research in synthetic biology: Some critical thoughts. *Nanoethics* 10:201–213.

Hallinan, J., A. Wipat, R. Kitney, S. Woods, K. Taylor, and A. Goñi-Moreno. 2019. Future-proofing synthetic biology: Educating the next generation. *Engineering Biology* 3 (2): 25–31.

Hammersley, B. 2009. At home with the DNA hackers. *Wired*, August 10. https://www.wired.co.uk/article/at-home-with-the-dna-hackers.

Haraway, D. 1985. A manifesto for cyborgs: Science, technology, and socialist feminism in the 1980s. *Socialist Review* 80:65–108.

Haraway, D. 1988. Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies* 14 (3): 575–599.

Haraway, D. 1997. *Modest_Witness@Second_Millennium.FemaleMan©_Meets_OncoMouse™: Feminism and Technoscience*. New York: Routledge.

Haraway, D. 2008. *When Species Meet*. Minneapolis: University of Minnesota Press.

Haraway, D. 2014. SF: String figures, multispecies muddles, staying with the trouble. Keynote presentation at the University of Alberta Faculty Club, Edmonton, Canada, March 24. YouTube video, 1:48:45. https://www.youtube.com/watch?v=Z1uTVnhIHS8.

Harding, S. 1992. Rethinking standpoint epistemology: What is "strong objectivity"? *Centennial Review* 36 (3): 437–470.

Heeney, C. 2017. An "ethical moment" in data sharing. *Science, Technology & Human Values* 42 (1): 3–28.

Hellsten, I., and B. Nerlich. 2011. Synthetic biology: Building the language for a new science brick by metaphorical brick. *New Genetics and Society* 30 (4): 375–397.

Henke, C., and T. Gieryn. 2008. Sites of scientific practice: The enduring importance of place. In *Handbook of Science and Technology Studies*, 3rd ed., edited by E. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman, 353–377. Cambridge, MA: MIT Press.

Henkel, J., and S. Maurer. 2009. Parts, property and sharing. *Nature Biotechnology* 27 (12): 1095–1098.

Henry, J. 2008. Historical and other studies of science, technology and medicine in the University of Edinburgh. *Notes and Records of the Royal Society* 62:223–235.

Hesjedal, M., A. Åm, K. Sørensen, and R. Strand. 2020. Transforming scientists' understanding of science–society relations: Stimulating double-loop learning when teaching RRI. *Science and Engineering Ethics* 26:1633–1653.

Hess, D. 2001. Ethnography and the development of science and technology studies. In *Handbook of Ethnography*, edited by P. Atkinson, A. Coffey, S. Delamont, J. Lofland, and L. Lofland, 234–245. Los Angeles: Sage.

Heynen, H. 2005. Modernity and domesticity: Tensions and contradictions. In *Negotiating Domesticity: Spatial Productions of Gender in Modern Architecture*, edited by H. Heynen and G. Baydar, 1–29. London: Routledge.

Hilgartner, S., B. Prainsack, and J. Hurlbut. 2017. Ethics in governance in genomics and beyond. In *Handbook of Science and Technology Studies*, 4th ed., edited by U. Felt, R. Fouché, C. Miller, and L. Smith-Doerr, 823–851. Cambridge, MA: MIT Press.

Hine, C. 2007. Multi-sited ethnography as a middle range methodology for contemporary STS. *Science, Technology & Human Values* 32 (6): 652–671.

Holbraad, M., M. Pedersen, and E. Viveiros de Castro. 2014. The politics of ontology: Anthropological positions. *Cultural Anthropology*, January 13. https://culanth.org/fieldsights/the-politics-of-ontology-anthropological-positions.

Holmes, D., and G. Marcus. 2008. Collaboration today and the re-imagination of the classic scene of fieldwork encounter. *Collaborative Anthropologies* 1:81–101.

Horst, M. 2013. Learning from discomfort: Science communication experiments between diffusion, dialogue and emergence. In *Knowledge and Power in Collaborative Research: A Reflexive Approach*, edited by L. Philips, E. Gunnarsson, M. Kristensen, and M. Vehvilainen, 21–41. London: Routledge.

Humphrey, C. 2007. Insider-outsider: Activating the hyphen. *Action Research* 5 (1): 11–26.

Ilynska, L., O. Ivanova, and Z. Senko. 2016. Rhetoric of scientific text translation. *Procedia: Social and Behavioral Sciences* 231:84–91.

Ingold, T. 2013. *Making: Anthropology, Archaeology, Art and Architecture*. London: Routledge.

Ingold, T. 2014. That's enough about ethnography! *HAU: Journal of Ethnographic Theory* 4 (1): 383–395.

Irwin, A. 2008. Risk, science and public communication: Third-order thinking about scientific culture. In *Routledge Handbook of Public Communication of Science and Technology*, edited by M. Bucchi and B. Trench, 199–211. London: Routledge.

Irwin, A. 2015. On the local constitution of global futures. *Nordic Journal of Science and Technology Studies* 3 (2): 24–33.

Jasanoff, S. 1999. STS and public policy: Getting beyond deconstruction. *Science, Technology and Society* 4 (1): 59–72.

Jasanoff, S. 2005. *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ: Princeton University Press.

Jasanoff, S. 2010. A field of its own: The emergence of science and technology studies. In *Oxford Handbook of Interdisciplinarity*, edited by R. Frodeman, J. Thompson Klein, and C. Mitcham, 191–205. Oxford: Oxford University Press.

Jasanoff, S. 2012. Genealogies of STS. *Social Studies of Science* 42 (3): 435–441.

Jasanoff, S. 2016. The floating ampersand: STS past and STS to come. *Engaging Science, Technology, and Society* 2:227–237.

Johung, J. 2016. Speculative life: Art, synthetic biology and blueprints for the unknown. *Theory, Culture & Society* 33 (3): 175–188.

Joly, P.-B. 2015. Governing emerging technologies: The need to think outside the (black) box. In *Science and Democracy: Making Knowledge and Making Power in the Biosciences and Beyond*, edited by S. Hilgartner, C. Miller, and R. Hagendijk. New York: Routledge.

Joly, P.-B. 2019. Alternative theories of innovation? The contribution of STS. Presentation at the Society for Social Studies of Science annual meeting, New Orleans, September 4–7.

Joly, P.-B., A. Rip, and M. Callon. 2010. Reinventing innovation. In *The Governance of Innovation: Firms, Clusters and Institutions in a Changing Setting*, edited by M. Arentsen, W. van Rossum, and B. Steenge, 19–32. Cheltenham: Edward Elgar.

Jordan, K., and M. Lynch. 1992. The sociology of a genetic engineering technique: Ritual and rationality in the performance of the plasmid prep. In *The Right Tools for* *the Job: At Work in 20th Century Life Sciences*, edited by A. Clarke and J. Fujimura, 77–114. Princeton, NJ: Princeton University Press.

Jun, N. 2011. Deleuze, values and normativity. In *Deleuze and Ethics*, edited by N. Jun and D. Smith, 89–107. Edinburgh: Edinburgh University Press.

Kaebnick, G., M. Gusmano, and T. Murray. 2014a. The ethics of synthetic biology: Next steps and prior questions. *The Hastings Center Report* 44 (6): S4–S26.

Kaebnick, G., M. Gusmano, and T. Murray. 2014b. Synthetic future: Can we create what we want out of synthetic biology? Special issue, *The Hastings Center Report* 44 (6).

Kattirtzi, M. and A. Stirling. 2018. Challenging power, constructing boundaries, and confronting anxieties: Michael Kattirtzi talks with Andrew Stirling. *Engaging Science, Technology, and Society* 4:386–407.

Kelly, A., and J. Lezaun. 2017. The wild indoors: Room-spaces of scientific inquiry. *Cultural Anthropology* 32 (3): 367–398.

Kennard, J., and N. James. 1986. Thrombolites and stromatolites: Two distinct types of microbial structures. *PALAIOS* 1 (5): 492–503.

Kerr, A., and L. Garforth. 2016. Affective practices, care and bioscience: A study of two laboratories. *Sociological Review* 64:3–20.

Kieniewicz, J. 2014. Q&A: Drew Endy on Design for Life. *PLOS Blogs*, July 2. https://theplosblog.plos.org/2014/07/synthetic-aesthetics-drew-endy-on-design-for-life/.

Knorr Cetina, K. 1995. Laboratory studies: The cultural approach to the study of science. In *Handbook of Science and Technology Studies*, edited by S. Jasanoff, G. Markle, J. Peterson, and T. Pinch, 140–166. Cambridge, MA: MIT Press.

Kondo, D. 1986. Dissolution and reconstitution of self: Implications for anthropological epistemology. *Cultural Anthropology* 1 (1): 74–88.

Koskinen, R. 2017. Synthetic biology and the search for alternative genetic systems: Taking how-possibly models seriously. *European Journal for the Philosophy of Science* 7:493–506.

Latimer, J. 2019. Science under siege? Being alongside the life sciences, giving science life. *Sociological Review Monographs* 67 (2): 264–286.

Latimer, J., and D. Lopez. 2019. Intimate entanglements: Affects, more-than-human intimacies and the politics of relations in science and technology. *Sociological Review Monographs* 67 (2): 247–263.

Latour, B. 2005. *Reassembling the Social*. Oxford: Oxford University Press.

Latour, B., and S. Woolgar. 1986. *Laboratory Life: The Construction of Scientific Facts*. Princeton, NJ: Princeton University Press.

Law, J., and A. Mol. 2001. Situating technoscience: An inquiry into spatialities. *Environment and Planning D: Society and Space* 19 (5): 609–621.

Leach, M., J. Rockström, P. Raskin, I. Scoones, A. Stirling, A. Smith, J. Thompson et al. 2012. Transforming innovation for sustainability. *Ecology and Society* 17 (2): 11.

Lewens, T. 2013. From bricolage to BioBricks. *Studies in History and Philosophy of Biological and Biomedical Sciences* 44 (4 Pt B): 641–648.

Liboiron, M. 2016. Care and solidarity are conditions for interventionist research. *Engaging Science, Technology, and Society* 2:67–72.

Livingstone, D. 2003. *Putting Science in Its Place: Geographies of Scientific Knowledge*. Chicago: University of Chicago Press.

Lohan, M. 2000. Come back public/private; (almost) all is forgiven: Using feminist methodologies in researching information communication technologies. *Women's Studies International Forum* 23 (1): 107–117.

Lozano, A. 2018. Reframing the public sociology debate: Towards collaborative and decolonial praxis. *Current Sociology* 66 (1): 92–109.

Lynch, M. 2000. Against reflexivity as an academic virtue and source of privileged knowledge. *Theory, Culture and Society* 17 (3): 26–54.

Lynch, M. 2009. Science as a vacation: Deficits, surfeits, PUSS, and doing your own job. *Organization* 16 (1): 101–119.

Lynch, M., and S. Cole. 2005. Science and technology studies on trial: Dilemmas of expertise. *Social Studies of Science* 35 (2): 269–311.

Macnaghten, P. 2016. The metis of responsible innovation: Helping society to get better at the conversation between today and tomorrow. Lecture, Wageningen University, Netherlands, May 12. https://edepot.wur.nl/410400.

Mansy, S., and S. Pohflepp. 2014. Living machines. In *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*, edited by A. D. Ginsberg, J. Calvert, P. Schyfter, A. Elfick, and D. Endy, 247–258. Cambridge, MA: MIT Press.

Marcus, G. 1995. Ethnography in/of the world system: The emergence of multi-sited ethnography. *Annual Review of Anthropology* 24:95–117.

Marcus, G. 1997. The uses of complicity in the changing mise-en-scène of anthropological field work. *Representations* 59 (13): 85–108.

Marcus, G. 2008. The end(s) of ethnography: Social/cultural anthropology's signature form of producing knowledge in transition. *Cultural Anthropology* 23 (1): 1–14.

Marcus, G. 2013. Experimental forms for the expression of norms in the ethnography of the contemporary. *HAU: Journal of Ethnographic Theory* 3 (2): 197–217.

Marres, N., M. Guggenheim, and A. Wilkie. 2018. *Inventing the Social*. Manchester: Mattering Press.

Marris, C. 2015. The construction of imaginaries of the public as a threat to synthetic biology. *Science as Culture* 24 (1): 83–98.

Marris, C., and J. Calvert. 2020. Science and technology studies in policy: The UK Synthetic Biology Roadmap. *Science, Technology & Human Values* 45 (1): 34–61.

Martin, B. 1996. Sticking a needle into science: The case of polio vaccines and the origin of AIDS. *Social Studies of Science* 26:245–276.

Matheson, S. 2017. Engineering a biology revolution. *Cell* 168:329–332.

Mazanderani, F., and B. Latour. 2018. The whole world is becoming science studies: Fadhila Mazanderani talks with Bruno Latour. *Engaging Science, Technology, and Society* 4:284–302.

McDowall, W. 2012. Technology roadmaps for transition management: The case of hydrogen energy. *Technological Forecasting and Social Change* 79 (3): 530–542.

Meyer, M. 2013. Domesticating and democratizing science: A geography of do-it-yourself biology. *Journal of Material Culture* 18 (2): 117–134.

Michael, M. 2012. De-signing the object of sociology: Toward an “idiotic” methodology. *Sociological Review* 60 (S1): 166–183.

Mikami, K., and S. Woolgar. 2018. STS as a program of ontological disobedience: Koichi Mikami talks with Steve Woolgar. *Engaging Science, Technology, and Society* 4:303–319.

Mol, A. 2002. *The Body Multiple: Ontology in Medical Practice*. Durham, NC: Duke University Press.

Mooallem, J. 2010. Do-it-yourself genetic engineering. *New York Times*, February 14. https://library.wur.nl/WebQuery/file/cogem/cogem_t4c770e7d_001.pdf.

Mosse, D. 2006. Anti-social anthropology? Objectivity, objection, and the ethnography of public policy and professional communities. *Journal of the Royal Anthropological Institute* 12:935–956.

Moulaert, F., D. MacCallum, and J. Hiller. 2013. Social innovation: Intuition, precept, concept, theory and practice. In *The International Handbook on Social Innovation*, edited by F. Moulaert, D. MacCallum, A. Mehmood, and A. Hamdouch, 13–24. Cheltenham: Edward Elgar.

Müller, R. 2017. Crafting a career in STS: Meaning making, assessment, and interdisciplinary engagement. *Engaging Science, Technology, and Society* 3:84–91.

Myers, N. 2015. *Rendering Life Molecular*. Durham, NC: Duke University Press.

National Academies of Sciences, Engineering, and Medicine. 2016. *Making the Living World Engineerable: Science, Practice, and Policy: Proceedings of a Workshop—in Brief*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24656.

Nature. 2004. Going public. *Nature* 431 (October 21): 883.

NEST. 2005. *Synthetic Biology: Applying Engineering to Biology. Report of a NEST High-Level Expert Group*. Luxembourg: European Communities. https://web.archive.org/web/20210424065341/http://www.eurosfaire.prd.fr/nest/documents/pdf/NEST_syntheticbiology_b5_eur21796_en.pdf.

Nordmann, A. 2016. Synbio recreating biology. Presentation at Synenergene Forum, Amsterdam, Netherlands, June 24–25, 2016.

Nordmann, A., and A. Rip. 2009. Mind the gap revisited. *Nature Nanotechnology* 4:273–274.

Nowotny, H. 2007. How many policy rooms are there? *Science, Technology & Human Values* 32 (4): 479–490.

Nuffield. 2012. *Emerging Biotechnologies: Technology, Choice and the Public Good*. London: Nuffield Council on Bioethics.

Oldenburg, R. 1999. *The Great Good Place: Cafes, Coffee Shops, Bookstores, Bars, Hair Salons, and Other Hangouts at the Heart of a Community*. New York: Marlowe.

Oldham, P., S. Hall, and G. Burton. 2012. Synthetic biology: Mapping the scientific landscape. *PLOS One* 7 (4): e34368. https://doi.org/10.1371/journal.pone.0034368.

O'Malley, M. 2010. Making knowledge in synthetic biology: Design meets kludge. *Biological Theory* 4 (4): 378–389.

O'Malley, M., A. Powell, J. Davies, and J. Calvert. 2008. Knowledge-making distinctions in synthetic biology. *BioEssays* 30 (1): 57–65.

Ophir, A. 1991. A place of knowledge recreated: The library of Michel de Montaigne. *Science in Context* 4 (1): 163–189.

Ortner, S. 2010. Access: Reflections on studying up in Hollywood. *Ethnography* 11:211–233.

Osborne, G. 2012. Speech by the Chancellor of the Exchequer, Rt Hon George Osborne MP, to the Royal Society, London, November 9. https://www.gov.uk/government/speeches/speech-by-the-chancellor-of-the-exchequer-rt-hon-george-osborne-mp-to-the-royal-society.

Owen, R. 2014. The UK Engineering and Physical Sciences Research Council's commitment to a framework for responsible innovation. *Journal of Responsible Innovation* 1 (1): 113–117.

Owen, R. 2016. Responsible research and innovation in Europe and across the world. Keynote presentation at the RRI Conference, Brussels, Belgium, January 14–19. YouTube video, 24:51. https://www.youtube.com/watch?v=11CCQ0rZ4tU.

Owen, R., P. Macnaghten, and J. Stilgoe. 2012. Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy* 39:751–760.

Owen, R., and M. Pansera. 2019. Responsible innovation and responsible research and innovation. In *Handbook on Science and Public Policy*, edited by D. Simon, S. Kuhlmann, J. Stamm, and W. Canzler, 26–48. Cheltenham: Edward Elgar.

Owten, H., and J. Allen-Collinson. 2014. Close but not too close: Friendship as method(ology) in ethnographic research encounters. *Journal of Contemporary Ethnography* 43 (3): 283–305.

Oxford Dictionaries. 2016. Experiment. Oxford: Oxford University Press. https://web.archive.org/web/20160902010016/http://www.oxforddictionaries.com/definition/english/experiment.

Parthasarathy, S. 2019. Innovations. Panel at the Society for Social Studies of Science annual meeting, New Orleans, September 4–7.

Peirce, C. 1998. *The Essential Peirce: Selected Philosophical Writings*. Vol. 2, *1893–1913*. Bloomington: Indiana University Press.

Pfotenhauer, S. 2019. Discussant comments in session "Innovation under fire: Shifting imaginaries of science, technology and society governance." Society for Social Studies of Science annual meeting, New Orleans, September 4–7.

Pottage, A. 2014. Review of P. Rabinow and G. Bennett, *Designing Human Practices: An Experiment with Synthetic Biology*. *Journal of the Royal Anthropological Institute* 20:362–366.

Prainsack, B. 2018. The "we" in the "me": Solidarity and health care in the era of personalized medicine. *Science, Technology & Human Values* 43 (1): 21–44.

Preston, C. 2008. Synthetic biology: Drawing a line in Darwin's sand. *Environmental Values* 17 (1): 23–39.

Pretorius, I., and J. Boeke. 2018. Yeast 2.0—connecting the dots in the construction of the world's first functional synthetic eukaryotic genome. *FEMS Yeast Research* 18 (4). https://doi.org/10.1093/femsyr/foy032.

Priaulx, N. 2013. The troubled identity of the bioethicist. *Health Care Analysis* 21:6–19.

Rabinow, P., and G. Bennett. 2012. *Designing Human Practices: An Experiment with Synthetic Biology*. Chicago: University of Chicago Press.

Radder, H. 2009. Why technologies are inherently normative. In *Philosophy of Technology and Engineering Sciences*, edited by A. Meijers, 887–921. Amsterdam: Elsevier.

Rai, A., and J. Boyle. 2007. Synthetic biology: Caught between property rights, the public domain, and the commons. *PLOS Biology* 5 (3): e58.

Reardon, J. 2013. On the emergence of science and justice. *Science, Technology & Human Values* 38 (2): 176–200.

Rheinberger, H.-J. 1997. *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*. Stanford, CA: Stanford University Press.

Ribeiro, B., and P. Shapira. 2020. Private and public values of innovation: A patent analysis of synthetic biology. *Research Policy* 49 (1): 103875.

Richardson, S. 2017. Principles of genome design. Presentation at SB7.0: The Seventh International Meeting on Synthetic Biology, National University of Singapore, June 13–16.

Riles, A. 2015. From comparison to collaboration: Experiments with a new scholarly and political form. *Law and Contemporary Problems* 78 (1–2): 146–183.

Riley, D. 2019. Pipelines, persistence, and perfidy: Institutional unknowing and betrayal trauma in engineering. *Feminist Formations* 31 (1): 1–19.

Rip, A. 1999. STS in Europe. *Science, Technology and Society* 4 (1): 73–80.

Rip, A. 2006a. A co-evolutionary approach to reflexive governance—and its ironies. In *Reflexive Governance for Sustainable Development*, edited by J. Voss, D. Bauknecht, and R. Kemp, 82–100. Cheltenham: Edward Elgar.

Rip, A. 2006b. Folk theories of nanotechnologists. *Science as Culture* 15 (4): 349–365.

Rip, A. 2014. The past and future of RRI. *Life Sciences, Society and Policy* 10:17. http://www.lsspjournal.com/content/10/1/17.

Rip, A. 2016. The clothes of the emperor: An essay on RRI in and around Brussels. *Journal of Responsible Innovation* 3 (3): 290–304.

Rip, A. 2018. "Things can be done here that cannot so easily be done elsewhere": Jane Calvert talks with Arie Rip. *Engaging Science, Technology, and Society* 4:183–201.

Rip, A., and E. Boeker. 1975. Scientists and social responsibility in the Netherlands. *Social Studies of Science* 5 (4): 457–484.

Rip, A., and P.-B. Joly. 2012. Emerging spaces and governance: A position paper for EU-SPRI. December 3. https://www.researchgate.net/profile/Andy_Stirling/publication/263962630_Emerging_Spaces_and_Governance_A_position_paper_for_EU-SPRI/links/00b4953c67201913bd000000.pdf.

Rip, A., and D. Robinson. 2013. Constructive technology assessment and the methodology of insertion. In *Opening Up the Laboratory: Approaches to Early Engagement with New Technology*, edited by N. Doorn, D. Schuurbiers, I. van de Poel, and M. Gorman, 37–53. Dordrecht: Springer.

Roberts, J. 2010. Reflections of an unrepentant plastiphobe: Plasticity and the STS life. *Science as Culture* 19 (1): 101–120.

Rogers, H., M. Halpern, D. Hannah, and K. Ridder-Vignone. 2021. *Routledge Handbook of Art, Science, and Technology Studies*. London: Routledge.

Roosth, S. 2017. *Synthetic: How Life Got Made*. Chicago: University of Chicago Press.

Roy, R. 2018. Decolonise science: Time to end another imperial era. *The Conversation*, April 5. https://theconversation.com/decolonise-science-time-to-end-another-imperial-era-89189.

Royal Academy of Engineering. 2009. *Synthetic Biology: Scope, Applications and Implications*. London: Royal Academy of Engineering. https://raeng.org.uk/media/fvwdlqmx/synthetic_biology.pdf.

Salter, C., R. Burri, and J. Dumit. 2017. Art, design, and performance. In *Handbook of Science and Technology Studies*, 4th ed., edited by U. Felt, R. Fouché, C. Miller, and L. Smith-Doerr, 139–167. Cambridge, MA: MIT Press.

Sanchez-Criado, T., and A. Estalella. 2017. *Experimental Collaborations: Ethnography through Fieldwork Devices*. New York: Berghahn Books.

SBLC. 2016a. *Biodesign for the Bioeconomy: UK Synthetic Biology Strategic Plan 2016*. London: Synthetic Biology Leadership Council. Original version no longer available online, replaced by SBLC 2016b.

SBLC. 2016b. *Biodesign for the Bioeconomy: UK Synthetic Biology Strategic Plan 2016*. London: Synthetic Biology Leadership Council. https://ktn-uk.org/perspectives/biodesign-for-the-bioeconomy-uk-strategic-plan-for-synthetic-biology/.

SBRCG. 2012. *A Synthetic Biology Roadmap for the UK*. Swindon: Technology Strategy Board.

Schnalzer, R. 2020. Is time flying by oddly quickly during COVID-19? Here's why you may feel that way. *Los Angeles Times,* May 1. https://www.latimes.com/lifestyle/story/2020-05-01/does-it-feel-like-like-time-is-flying-by-during-coronavirus-quarantine-heres-why.

Schot, J., and A. Rip. 1997. The past and future of constructive technology assessment. *Technological Forecasting and Social Change* 54:251–268.

Schyfter, P., and J. Calvert. 2015. Intentions, expectations and institutions: Engineering the future of synthetic biology in the US and the UK. *Science as Culture* 24 (4): 359–383.

Secord, A. 1994. Science in the pub: Artisan botanists in early nineteenth-century Lancashire. *History of Science* 32 (97): 269–315.

Shapin, S. 1988. The house of experiment in seventeenth-century England. *Isis* 79 (3): 373–404.

Shapin, S. 1995. Here and everywhere: Sociology of scientific knowledge. *Annual Review of Sociology* 21: 289–321.

Shapin, S. 2012. The ivory tower: The history of a figure of speech and its cultural uses. *British Journal for the History of Science* 45 (1): 1–27.

Shapin, S. 2020. Breakfast at Buck's: Informality, intimacy, and innovation in Silicon Valley. *Osiris* 35:324–347.

Shapiro, D. 1995. Nuffield Council on Bioethics. *Politics and the Life Sciences* 14 (2): 263–266.

Sigl, L. 2016. "Frugal innovation"—An inquiry into a blind spot in STS. *Reflections: Blog of STS Department at the University of Vienna*, June 13. https://rri.univie.ac.at/einzelansicht-news-events/news/frugal-innovation-an-inquiry-into-a-blind-spot-in-sts/.

Siler, K. 2012. Nascent institutional strategy in dynamic fields: The diffusion of science and technology studies. *American Behavioral Scientist* 56 (10): 1388–1412.

Sims, C. 2017. The politics of design, design as politics. In *The Routledge Companion to Digital Ethnography*, edited by L. Hjorth, H. Horst, A. Galloway, and G. Bell, 439–447. Routledge: New York.

Sismondo, S. 2008. Science and technology studies and an engaged program. In *Handbook of Science and Technology Studies*, 3rd ed., edited by E. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman, 13–30. Cambridge, MA: MIT Press.

Skelton, A. 1997. Conferences, conferences, conferences? *Teaching in Higher Education* 2 (1): 69–72.

Smith, H., C. Hutchinson, C. Pfannkoch, and J. C. Venter. 2003. Generating a synthetic genome by whole genome assembly: φX174 bacteriophage from synthetic oligonucleotides. *Proceedings of the National Academy of Sciences* 100 (26): 15440–15445.

Smith, R., S. Hartley, P. Middleton, and T. Jewett. 2021. Knowing when to talk? Plant genome editing as a site for pre-engagement institutional reflexivity. *Public Understanding of Science* 30 (6): 740–758.

Smith, R., K. Kawamura, E. Szymanski, R. Shineha, and J. Calvert. 2024. The soba restaurant and the oyster bar: Peripheral spaces for responsible research and innovation. Forthcoming in *East Asian Science, Technology and Society*.

Smolke, C. 2009. Building outside of the box: iGEM and the BioBricks Foundation. *Nature Biotechnology* 27:1099–1102.

Soete, L. 2019. Science, technology and innovation studies at a crossroad: SPRU as case study. *Research Policy* 48 (4): 849–857.

Sormani, P., G. Carbone, and P. Gisler. 2019. *Practicing Art/Science: Experiments in an Emerging Field*. London: Routledge.

Stanley, L. 1993. The knowing because experiencing subject: Narratives, lives, and autobiography. *Women's Studies International Forum* 16 (3): 205–215.

Steen, M., and S. Dhondt. 2010. Slow innovation. Presentation at 26th EGOS Colloquium, Lisbon, Portugal, July 1–3. https://www.researchgate.net/profile/Steven_Dhondt/publication/268061374_Slow_Innovation/links/54731a590cf2d67fc035dd90.pdf.

Stengers, I. 2011. "Another science is possible!" A plea for slow science. Inaugural lecture, Willy Calewaert chair, Faculté de Philosophie et Lettres, Université libre de Bruxelles, December 13. https://threerottenpotatoes.files.wordpress.com/2011/06/stengers2011_pleaslowscience.pdf.

Stenner, P. 2015. *Liminality and Experience: A Transdisciplinary Approach to the Psychosocial*. London: Palgrave Macmillan.

Stephens, N., and R. Dimond. 2016. Debating CRISPR/cas9 and mitochondrial donation: Continuity and transition performances at scientific conferences. *Engaging Science, Technology, and Society* 2:312–321.

Stevens, J. 2008. Biotech patronage and the making of homo DNA. In *Tactical Biopolitics: Art, Activism, and Technoscience*, edited by B. da Costa and K. Philip, 43–62. Cambridge, MA: MIT Press.

Stilgoe, J. 2015. *Experiment Earth: Responsible Innovation in Geoengineering*. London: Routledge.

Stilgoe, J., and D. Guston. 2017. Responsible research and innovation. In *Handbook of Science and Technology Studies*, 4th ed., edited by U. Felt, R. Fouché, C. Miller, and L. Smith-Doerr, 853–880. Cambridge, MA: MIT Press.

Stilgoe, J., R. Owen, and P. Macnaghten. 2013. Developing a framework for responsible innovation. *Research Policy* 42 (9): 1568–1580.

Stirling, A. 2008. "Opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. *Science, Technology & Human Values* 33 (2): 262–294.

Stirling, A. 2016. Knowing doing governing: Realizing heterodyne democracies. In *Knowing Governance: The Epistemic Construction of Political Order*, edited by J.-P. Voß and R. Freeman, 259–289. Basingstoke: Palgrave Macmillan.

Strohm, K. 2012. When anthropology meets contemporary art: Notes for a politics of collaboration. *Collaborative Anthropologies* 5:98–124.

Suchman, L. 2014. Society for Social Studies of Science 2014 Presidential Election: Candidate bio and statement, May 17. https://www.research.lancs.ac.uk/portal/en/activities/society-for-social-studies-of-science-external-organisation(af350404-3c0c-471c-b95c-18e4715e6a0e).html.

Supper, A., and G. Somsen. 2018. A panel on panels: Studying academic conference practice. Session at the European Association for the Study of Science and Technology, July 26. https://nomadit.co.uk/conference/easst2018/p/6192.

Szakolczai, A. 2009. Liminality and experience: Structuring transitory situations and transformative events. *International Political Anthropology* (2) 1: 141–172.

Szerszynski, B., and M. Galarraga. 2013. Geoengineering knowledge: Interdisciplinarity and the shaping of climate engineering research. *Environment and Planning A: Economy and Space* 45 (12): 2817–2824.

Szymanski, E., and J. Calvert. 2018. Designing with living systems in the synthetic yeast project. *Nature Communications* 9:2950. https://doi.org/10.1038/s41467-018-05332-z.

Taylor, C. 2002. Modern social imaginaries. *Public Culture* 14 (1): 91–124.

Thompson, J. 1993. The theory of the public sphere. *Theory, Culture & Society* 10:173–198.

Tillmann-Healy, L. 2003. Friendship as method. *Qualitative Inquiry* 9 (5): 729–749.

Tsing, A. 2015. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton, NJ: Princeton University Press.

Uffindel, D. 2012. Perspectives on synthetic biology from within the political system. Presentation at Synthetic Biology for the Next Generation: The Six Academies Symposium, Washington, DC, June 12–13. http://events.tvworldwide.com/Events/IOM/NAS-120612?%20VID=events/nas/120612_NAS_SyntheticBiology_1415.flv.

Urquhart, J. 2014. Synthetic yeast chromosome is fully functional. *Royal Society of Chemistry*, March 27. https://www.chemistryworld.com/news/synthetic-yeastchromosome-is-fully-functional/7222.article.

Vaage, N. 2016. What ethics for bioart? *Nanoethics* 10:87–104.

Vaage, N. 2017. Fringe biotechnology. *BioSocieties* 12 (1): 109–131.

van Oudheusden, M., and B. Laurent. 2013. Shifting and deepening engagements: Experimental normativity in public participation in science and technology. *Science, Technology & Innovation Studies* 9 (1): 3–22.

Viseu, A. 2015. Caring for nanotechnology? Being an integrated social scientist. *Social Studies of Science* 45 (5): 642–664.

von Hippel, E. 2005. *Democratizing Innovation*. Cambridge, MA: MIT Press.

Wadey, C., I. Deese, D. Endy. 2005. *Adventures in Synthetic Biology*. OpenWetWare & Nature Publishing Group. http://hdl.handle.net/1721.1/46337.

Webster, A. 2007. Crossing Boundaries: Social science in the policy room. *Science, Technology & Human Values* 32 (4): 458–478.

Wheater, K. 2021. A summer contemplation. *Bulletin Staff Magazine*, University of Edinburgh, July 14. https://bulletin.ed.ac.uk/2021/07/14/a-summer-contemplation/.

Wiek, A., D. Guston, E. Frow, and J. Calvert. 2012. Sustainability and anticipatory governance in synthetic biology. *International Journal of Social Ecology and Sustainable Development* 3 (2): 25–38.

Wilkie, A., and M. Michael. 2015. The design studio as a centre of synthesis. In *Studio Studies: Operations, Topologies & Displacements*, edited by I. Farías and A. Wilkie, 25–39. New York: Routledge.

Willetts, D. 2012a. Our hi-tech future. Oral statement to Parliament, January 4. https://www.gov.uk/government/speeches/our-hi-tech-future--2.

Willetts, D. 2012b. Response to "A synthetic biology roadmap for the UK": Letter from David Willetts MP to Dr Lionel Clarke, November 9. https://www.gov.uk/government/publications/response-to-a-synthetic-biology-roadmap-for-the-uk-letter-from-david-willetts-mp-to-dr-lionel-clarke.

Willetts, D. 2013. *Eight Great Technologies*. London: Policy Exchange.

Wilsdon, J., and R. Willis. 2004. *See-Through Science: Why Public Engagement Needs to Move Upstream*. London: DEMOS. http://sro.sussex.ac.uk/id/eprint/47855/.

Wilson Center. 2015. *U.S. Trends in Synthetic Biology Research Funding*. Washington, DC: Synthetic Biology Project, Wilson Center. https://www.wilsoncenter.org/sites/default/files/media/documents/publication/final_web_print_sept2015.pdf.

Winner, L. 1980. Do artifacts have politics? *Daedalus* 109 (1): 121–136.

Woolf, V. 1929. *A Room of One's Own*. London: Hogarth Press.

Woolgar, S. 2005. Ontological disobedience—definitely! {maybe}. In *A Disobedient Generation*, edited by S. Turner and A. Sica, 309–324. Chicago: University of Chicago Press.

Woolgar, S., and G. Cooper. 1999. Do artefacts have ambivalence? *Social Studies of Science* 29 (3): 433–49.

Woolgar, S., C. Coopmans, and D. Neyland. 2009. Does STS mean business? *Organization* 16 (1): 5–30.

Woolgar, S., and J. Lezaun. 2013. The wrong bin bag: A turn to ontology in science and technology studies? *Social Studies of Science* 43 (3): 321–340.

Wynne, B. 1993. Public uptake of science: A case for institutional reflexivity. *Public Understanding of Science* 2 (4): 321–337.

Wynne, B. 2007. Dazzled by the mirage of influence? STS-SSK in multivalent registers of relevance. *Science, Technology & Human Values* 32 (4): 491–503.

York, E. 2018. Doing STS in STEM spaces: Experiments in critical participation. *Engineering Studies* 10 (1): 66–84.

Ziewitz, M., and M. Lynch. 2018. It's important to go to the laboratory. *Engaging Science, Technology, and Society* 4:366–385.

Zuiderent-Jerak, T. 2015. *Situated Intervention: Sociological Experiments in Health Care*. Cambridge, MA: MIT Press.

Zuiderent-Jerak, T. 2016. If intervention is method, what are we learning? *Engaging Science, Technology, and Society* 2:73–82.

Zwart, H., L. Landeweerd, and A. van Rooij. 2014. Adapt or perish? Assessing the recent shift in the European research funding arena from "ELSA" to "RRI." *Life Sciences, Society and Policy* 10:11.

INDEX

Note: Page numbers in italics are figures. References to notes are indicated by 'n' after the page number.