HALLAM STEVENS

BIOTECHNOLOGY and Society

AN INTRODUCTION

UNIVERSITY OF CHICAGO PRESS

Chicago and London

CONTENTS

Introduction 1

PART I: THE LIMITS OF BIOTECHNOLOGY

Chapter 1: What Is Biotechnology? 15

Chapter 2: The Long History of Biotechnology 21

PART II: GENETIC ENGINEERING

Chapter 3: Inventing Genetic Engineering 35

Chapter 4: The Recombinant DNA Debates 50

PART III: OWNING LIFE

Chapter 5: Biotechnology and Business 65

Chapter 6: Patenting Life 79

PART IV: GENETICALLY MODIFIED FOODS

Chapter 7: Risk, Regulation, and Our Food 97

Chapter 8: The Economics of Eating 116

PART V: THE BOUNDARIES OF BODILY LIFE

Chapter 9: Owning Part of You 133

Chapter 10: Freezing, Banking, Crossing 144

PART VI: MAPPING GENES, MAKING SOCIETY

Chapter 11: Eugenics 159

Chapter 12: The Human Genome Project 174

PART VII: GENETIC TESTING, DISCRIMINATION, AND BIOETHICS

Chapter 13: Genetic Testing, Disability, and Discrimination 195

Chapter 14: Bioethics and Medicine 207

PART VIII: VIRGIN BIRTHS

Chapter 15: From the Pill to IVF 223

Chapter 16: Cloning 236

PART IX: RE-ROUTING LIFE

Chapter 17: Stem Cells 253

Chapter 18: Designer Babies 269

PART X: MINDING YOUR OWN BIOLOGICAL BUSINESS

Chapter 19: Drugs and Designer Bodies 279

Chapter 20: Personal Genomics 292

PART XI: BIOTECHNOLOGY AND DIVERSITY

Chapter 21: Biotechnology and Race 313

Chapter 22: Bioprospecting and Biocolonialism 327

PART XII: BIOLOGICAL FUTURES

Chapter 23: Synthetic Biology and Bioterrorism 345

Chapter 24: Biotechnology and Art 358

Conclusion: Eternal Life and the Posthuman Future 370

Acknowledgments 375

Index 377

INTRODUCTION

SCIENCE AND TECHNOLOGY IN CONTEXT

Christopher Reeve—best known for his role as Superman in the series of 1970s and 80s films—passed away in 2004. The causes were complications arising from a spinal injury he had suffered while horseback riding in 1995 and which had left him a quadriplegic. In the final years of his life, Reeve became a controversial figure. He argued forcefully that stem cell research had the potential to cure his paralysis and that of thousands of others. The restrictions on US federal government funding for stem cell research, enacted by George W. Bush in 2001, were delaying progress in this crucial area of medical research, Reeves said.

The supporters of the restrictions, many belonging to the Religious Right, argued that collecting human embryos for this research involved the destruction of life. Setting up a foundation to fund this research, Reeves became involved in a highly politicized and bitter struggle involving biotechnology and religion. Here, as elsewhere, the significance of biotechnology extends far beyond the walls of the laboratory or the hospital. "Making Superman walk again" linked stem cells to powerful cultural, religious, economic, and political issues that divide society. Biotechnologies have become objects in debates about the costs of health care, the appropriate roles of government regulation and funding, international scientific and economic competition, and our rights over our own bodies. On Wall Street, the fate of biotechnology and pharmaceutical companies influences the global economy. Questions central to biotechnology—such as those about the ownership of genes or cells—are hotly contested in the courts. Within popular culture, Hollywood movie plots center on cyborgs, deadly viruses, and artificial organs. More and more of the food that most of us buy in the supermarket contains genetically modified ingredients. And most everyone knows Dolly the sheep. So, understanding biotechnology—what it is, and where it came from—is undoubtedly important. But this means not merely understanding biotechnology as a technical phenomenon, but also seeing how it fits into our society. Such a perspective will shed light on some of the most pressing and controversial issues of our time. Biotechnology reveals much about present-day relationships between nature and culture, biology and technology, living and nonliving, human and

nonhuman. By studying and analyzing biotechnology we can come to see our own place in the world a little more clearly.

: : :

This book is intended to do two things. First, it is a history of biotechnology. It provides a narrative of how these technologies (and the industry that produces them) came into being, tracing some of the important historical transformations that biotechnology has engendered. Second, the book uses the tools of the social sciences (history, sociology, anthropology, philosophy, cultural studies) to analyze biotechnology. It critically examines biotechnology in a wide variety of contexts. Many of the arguments in this book work from the assumption that the technical and the social, the technical and the political, and the technical and the economic are always intertwined. It is impossible to understand the origins or significance of technical things without understanding their social, political, and economic context. There have been many books that examine the economic effects of biotechnology, or explore some of its ethical ramifications, or speculate about its possible consequences for the future. Rather than taking any one of these approaches, *Biotechnology and Society* synthesizes these different perspectives on biotechnology.

In the first chapter, a case is made that biotechnology should be understood as a *sociotechnical system*: a complex and interacting set of elements that includes both technical (test tubes, gene sequencing machines) and social things (laws, institutions, science fiction movies). Really understanding biotechnology means seeing the big picture, seeing the connections and interactions between all these things. One straightforward but powerful framework for analyzing technological constructs in this way is called *coproduction*. This idea suggests that the outcomes of science and technology are always coproduced by social and technical circumstances—we cannot understand stem cells or climate change or quantum mechanics without paying attention to both technical and social circumstances *at the same time*. One might even want to go so far as to say that the technical is inseparable or inextricable from the social—there is nothing that is technical that is not always also social. The Apollo spacecraft, for example, was no doubt a feat of science, engineering, and technical prowess; but its existence and design can be fully explained only by referring to the social, political, and economic conditions of the Cold War, the space race, nuclear fear, US prosperity, and peculiarly American conceptions of the "final frontier." All kinds of things in the world are coproduced by technological and social circumstances.

How might we discover the social or political aspects of things around us? Historians of technology have shown how even seemingly mundane objects

have "politics" built into them. Take a highway overpass, for instance. This seems like a fairly boring, neutral sort of object. Many such overpass bridges have been built all over the United States since the 1950s. In New York City, many such bridges were planned and designed by Robert Moses (1888–1981), one of the most influential urban planners of the twentieth century. Head of numerous public authorities in New York, Moses wielded wide-ranging power over the construction of public facilities around the city. Unfortunately, Moses was also a racist and publicly espoused racial segregation. In Brooklyn, this had an unusual consequence for road overpass bridges: Moses built them especially low. So low in fact that, while passenger cars could pass under them without issue, public buses could not use the roadways. Since it was mostly poor African-Americans who used the buses as their primary means of transportation, Moses knew that his low bridges limited the access of this minority to the beaches on Long Island. Moses did not want racial mixing on Jones Beach, Lido Beach, and Rockaway Beach, and built this prejudice into the design of his highways. The mundane highway overpass became an object that reflected a particular ideological agenda, expressing a political view in concrete and rebar. This is an extreme example, but it suggests how unpacking the history of an object reveals cultural and social meanings. This book will do a similar thing for genetically modified foods, stem cells, and personal genomics—it will open up their history and their politics.

These kinds of analyses—using coproduction and looking for the politics inside technologies—will help to expose the connections between biotech's technical side and its political and cultural dimensions. They will show the importance of thinking of biotechnology as a system that affects many aspects of our lives.

AUDIENCE AND SCOPE

Biotechnology and Society has several intended audiences. For the general reader, I hope that this book provides an introduction to the subject of biotechnology: what it is, where it came from, what its significance is, and where it might be leading us. For this audience the book can be read as a straightforward historical narrative. For students of "science studies," "science, technology, and society," or the history of science, the book provides a broad overview of the history of biotechnology. This is a starting point for further reading and research in this field; it introduces not only the main topics, but also most of the major theoretical and methodological approaches to this material. I have provided annotated bibliographies at the end of each chapter that suggest works that provide more detailed accounts and analyses of the subject matter. Finally, the book is aimed at biomedical scientists who

probably already know a lot about biotechnology as a technical field but wish to know more about its history. For these readers, I hope that connecting biotechnology to its various contexts helps them to see (and perhaps even do) their scientific work from new and broader perspectives.

Despite the emphasis on the social and political aspects of biotech, this book does not shy away from technical details. It is simply not possible to understand or analyze the social implications of biotechnology without some understanding of the science and technology itself. This book does not attempt to gloss over this detail: where necessary, scientific and technical concepts are explained from first principles, in plain language. In some cases, simplification is necessary. However, the aim is that the reader will come away with some technical knowledge about how particular aspects of biotechnology work, as well as an understanding of its historical and social contexts.

: : :

The definition of *biotechnology* I will offer in chapter 1 is wide: it applies to vitamin supplements and genetic counseling as well as much in between. Such a definition reminds us how much of our modern lives are intertwined with the biotechnological in some way or another. However, some selectivity is always necessary and it is worthwhile to point out some specific domains that this book does *not* examine in detail.

First, the book will have relatively little to say about "older" biotechnology, except in chapter 2 and except where it is useful to highlight similarities and differences with newer biotech objects and techniques. Other books have done an excellent job of tracing the prehistory of biotechnology, and the references to those works can be found in the Further Reading sections at the end of each chapter.

Second, this is not a book about the development of the biotech industry per se. The approach here is to understand biotechnology as a sociotechnical system. This system includes companies and economic elements (venture capitalists, stock markets). These are vital to the story of biotechnology. However, the emphasis here is on trying to understand how these financial and economic elements fit together with biological objects, social institutions, laws, and so forth to form the complex we call biotech. Once again, there are many books that have described the rise and development of the biotechnology industry, and I refer the reader to these works where appropriate.

Third, the chapters do not address many consequential developments in biology itself or in medical research and practice. Of course, biology and medicine do enter the story at particular points—especially where they have immediate and transformative social, political, and economic consequences

(for instance, the development of the contraceptive pill and psychoactive pharmaceuticals warrant particular attention). This is not to suggest that developments in biology and medicine are unimportant—on the contrary, they form the background to much of the history described here. However, by necessity, *Biotechnology and Society* focuses its attention on instances where contact between the biological and the social is at its sharpest.

Finally, although the book does pay attention to the relationships between biotechnology and culture, it is not about the public understanding or public reception or responses to biotechnology. Films, science fiction, and other technological "imaginaries" certainly play a role in shaping technologies and their patterns of use and acceptance; several examples of this will be discussed in detail. However, the emphasis is on understanding the interplay between culture and technology: it is not just a question of determining the impact of technology on culture, or the influence of culture on technologies. Rather, we need to examine the complex feedback loops (ramifying through politics, economics, law, medicine) through which each constantly remakes the other.

As a whole, *Biotechnology and Society* is not just about understanding the technological details of biotech, nor is it about understanding the effects of biotechnology on the economy, or the effects on medicine, or the effects on the law. Rather, it is about trying to comprehend the complex interconnections between all these elements. That is, it is about how biotech is transforming our society and culture as a whole. *Biotechnology and Society* is not just about technology, but also about *what we are becoming through this technology*.

: : :

Writing a book about such a diverse range of topics entails a further challenge. Biotechnology is a rapidly changing field. No doubt, by the time this book goes to press, some important new developments will have emerged. Does this mean that this book is already out of date? Fortunately, no. For one thing, the historical accounts will remain relevant, even if our perspective on the past changes on account of new discoveries or inventions. But the frameworks for analyzing biotechnology described here will continue to be applicable, too. These frameworks will continue to be relevant to new biotechnologies and the chapters here will continue to serve as examples of how we might think about these new discoveries and inventions critically from social, political, and economic viewpoints.

This book is composed of twenty-four short chapters. They tell the story of biotechnology in roughly chronological order. Each of these chapters can be approached on its own. However, more than chronology ties the chap-

ters together. Studying the history of biotechnology reveals some recurring themes. These themes summarize some of the lessons we might learn from a critical analysis of biotechnology and suggest how we might move forward in resolving some of the problems and debates that biotech raises.

FIVE THEMES

THEME 1: BIOTECH IS NOT NEW

There are a broad range of things that might count as biotechnology. When most people think of biotech, they think of recent techniques (such as direct manipulation of cells or DNA, for instance). Most of these technologies have been around only since the 1970s. But limiting our view of biotech to just DNA and stem cells seems, on closer examination, quite arbitrary. After all, genetically modifying corn (a recent practice) and selectively cross-pollinating corn to create larger ears (an ancient practice) both aim at the same end (increasing food yield). And, they're modifying the same object (that is, the maize genes). Admittedly, the genetic modification techniques are more direct and no doubt quicker, but there is something fundamentally similar going on. In chapter 2, I examine the history of beer as an extended example of how humans have been using biology (in this case yeast, a microorganism) for their own ends for many centuries. So at least in agriculture, baking, brewing, cheese-making, dye-making, and significant parts of the chemical industry, biotechnology has a long history. Parts of this history will enter into this book, although the book does not trace the long history of biotech in detail (if you are interested in this story, I recommend Robert Bud's *The Uses of Life*).

This long history is important for two reasons. First, showing that biotechnology has a history shows how some things that we think are radical and new about biotech are actually quite old. Showing that problems, debates, and controversies have a history can sometimes help us to resolve, or at least better understand, them. Contemporary debates about genetically modified foods, for instance, have parallels in debates about the Green Revolution in the 1960s and '70s and in British concerns about class and food resources in the nineteenth century. Putting these debates in this context suggests that some of the anxiety about genetic modification may have more to do with concern over the planet's diminishing resources than with new techniques, per se.

The second important reason for examining biotech's long history is that there are some special and interesting things about post-1970s biotechnology. The hype of new biotechnologies often makes everything seem novel. The longer history can present a point of comparison—it can help us pin down

what is really new and interesting about biotech in the twenty-first century. Such an analysis is important because of the political and economic stakes involved. Proponents of biotechnologies often have an interest in showing that many of its practices have a long history. Portraying it in this way may make biotechnologies seem less dangerous or frightening. Opponents of biotechnologies, too, may draw on historical examples intended to warn us about the dangers of meddling with nature. Examining the history of biotechnology in more detail will allow us to critically evaluate both kinds of claims.

THEME 2: PLASTICITY

In 1895, the renowned science fiction author H. G. Wells wrote an article for the London weekly, *The Saturday Review*, titled "The Limits of Individual Plasticity." Wells wrote:

> A living being may also be regarded as raw material, as something plastic, something that may be shaped and altered, that this, possibly, may be added and that eliminated, and the organism as a whole developed far beyond its apparent possibilities . . . a living thing might be taken in hand and so moulded and modified that at best it would retain scarcely anything of its inherent form and disposition; that the thread of life might be preserved unimpaired while shape and mental superstructure were so extensively recast as even to justify our regarding our result as a new variety of being.[1]

Although Wells was a novelist, he was also active in the science and politics of late Victorian Britain. Influenced by socialism, Wells was deeply interested in scientific questions about the molding or shaping of humans. *The Island of Dr. Moreau* (1896) is an extended consideration of this subject—a rogue scientist uses the techniques of vivisection to gradually transform animals into human-like forms. The novel is in part a warning about the dangers of unchecked scientific curiosity, but it also speculates about the "limits" of life's plasticity and raises the question, "How much could life be changed and still remain life?"

Much of contemporary biotechnology is an exploration of this question. What are the limits of life? To what degree can it be manipulated and shaped? What are the consequences of this shaping? The history of biotechnology is largely a history in which we have discovered that life is far more plastic than

1. H. G. Wells, "The Limits of Individual Plasticity," *Saturday Review*, January 19, 1895. Also reproduced in H. G. Wells, *H. G. Wells: Early Writings in Science and Science Fiction* (Berkeley: University of California Press, 1975), 36–39.

we thought. Much of the controversy about biotech is about coming to terms with this ability to intervene, manipulate, and reshape at will (biologists are often criticized for "playing God"). Following Wells, we might consider biotechnology as a set of ways in which living beings might be used as raw material. This also suggests a connection between controlling life in labs and controlling the lives of populations. Since scientists and others in the past have often thought of these two problems as connected, this book also considers them as inseparable parts of a whole that must be discussed together (genetics and eugenics, for instance).

THEME 3: PROMISE

Biotechnology is often portrayed as the science and technology of the future. When biotechnology is discussed in the media or in public forums, we hear mostly about the biotechnology that is to come: the breakthrough just about to be made, the life-saving drug just around the corner, the possibilities for extending life into distant, but not unimaginably far off, years to come. Whether or not biotechnology actually lives up to such promises, of course, remains to be seen. However, this book argues that these kinds of promises are constitutive of biotechnology—it is always oriented towards the future, the science of "never quite there." This is partly because of economics. As an industry, biotechnology needs to make promises to its investors that they will receive high returns. Those start-ups that can make big promises are likely to see the financial returns of the big investments. Here the economics of speculation crosses with the creativity of the laboratory to create what might be called *promissory science*.

But this hype associated with biotech also has another important source. Popular culture—especially science fiction in books, movies, and video games—also generates expectations and foreshadows the biotech developments of the future. These scientific and technical imaginaries exert an influence on how biotech develops, influencing the direction of scientists' own work. But they also, perhaps more importantly, influence how we understand biotechnologies: what we expect, what we desire, and what we fear. *Jurassic Park* (1993), *Outbreak* (1995), *Gattaca* (1997), *In Time* (2011), and even the X-Men movies (2000, 2003, 2006, 2009, 2011, 2014) shape our ideas about cloning, bioterrorism, genetic privacy, immortality, and genetic mutation. So analyzing biotechnology means paying careful attention to how cultural sources have shaped and are continuing to shape biotechnology, especially through hype, promise, and fear.

One of the most serious consequences of promissory science is that it makes biotech especially difficult to assess for the purposes of any kind of

debate. Biotechnology almost always requires weighing the value of present "knowns" against the promise of potential future benefits. Synthetic biology, for instance, creates a risk that some specially engineered organism could escape from its laboratory and run amok in the environment. Does this mean we should cease all research in synthetic biology? To make such a decision we need to balance these risks against the great promise, speculation, and hype about the potential future gains from this line of work (new therapies, new energy sources, etc.). Analyzing biotech as a promissory science means, as much as analyzing the science and technology itself, finding ways of analyzing the hype, speculation, and expectations that surround it.

THEME 4: BEYOND CONTROVERSY

Much of the popular attention devoted to biotechnology concerns a set of high-profile controversies. They include debates about the safety of genetically modified foods, worries about the privacy of genetic information, the possibilities of bioterrorism, biotech's contribution to the rising costs of health care, and the politically divisive debate about stem cell research. These are accompanied by smaller-scale battles including those concerning cloning (what forms are acceptable, for what purposes?), assisted reproductive therapies (who should have the right to use them?), the patentability of genetic information, and laboratory safety. These controversies are all too often framed around the question of "*should we or shouldn't we?*": Should we allow tax dollars to be spent on stem cell research or shouldn't we? Should we require genetically modified foods to be labeled in supermarkets or shouldn't we? Should we allow personal genomics companies access to our genomes or shouldn't we? And so on. Asking "should we or shouldn't we?" about various technologies is often important, and usually it is the most pressing question for immediate public policy purposes.

But this book encourages the reader to step back from "should we or shouldn't we?" This question all too often obscures or obfuscates a number of other more fundamental and sometimes more important questions that need to be asked about biotechnologies. First, asking questions about the history of biotechnologies can often reveal much about why a debate is taking place at all. Showing why an issue emerges at *this time* and in *that place* can tell us much about what is really at stake. Second, putting biotechnology in context can show how some controversies about technology are actually manifestations of more deeply rooted and long-term cultural conflicts. Third, often the "should we or shouldn't we?" debate proceeds without a clear analysis of who stands to gain and who stands to lose from particular developments. We need to ask questions that sort out the interwoven strands that connect

biotechnologies to the interests of governments, institutions, and corporations—often in obscure ways. The social sciences offer a range of tools and frameworks that go beyond the obvious ethical or moral questions in order to interrogate biotech from a variety of perspectives. Again, this is not to suggest that the ethical dimensions of biotechnology are not important, but rather to make sure we are fully equipped to provide solutions to moral quandaries that encompass more than just the technical dimensions of biotech.

THEME 5: RISK

Finally, biotechnology demands that we engage with the problem of risk. The biotech breakthroughs that offer great hope for curing cancer or cleaning up pollution also have the potential for great harms. These harms may be environmental or medical (posing a threat to human health), or they may be legal, social, and economic (inventions that are so disruptive that they destabilize). They may be immediate and predictable, or they may emerge only in the very long term (and be largely unforeseeable). The problem here is that most of the frameworks for assessing and understanding risk are unable to deal with the challenges posed by biotech. One issue is that risk management frameworks tend to try to measure costs versus benefits for a specific technology. In the case of biotechnologies, long-term costs and benefits may be hard to foresee. In addition, cost-benefit analyses tend to require some form of quantification—risks and rewards that can be measured in probabilities and dollars. The kinds of "social risks" that biotech often presents are hard to quantify and hence are often ignored by risk rubrics.

In the 1970s and '80s, there was a large public opposition to nuclear power in the Western world. Scientific experts (physicists, government officials) repeatedly and consistently assured the public that nuclear power was "safe" and that the risks were small. Yet the opposition continued, or even intensified. How and why did the public perceive the risk of nuclear power in this way? In the public imagination, nuclear power was tied to Cold War anxieties and the risks of nuclear war. Moreover, the public perceived the nuclear power industry as a hegemonic technological system that was associated with state control and increasing state power over people's lives. It was not that the public "didn't understand" nuclear power or were acting irrationally; in fact, in some sense, they understood nuclear power only too well. Public opposition reflected not just a technical assessment of risk, but a more holistic sociopolitical assessment of the cultural and political meanings of a nuclear power industry.

Brian Wynne, a sociologist who studies the public understanding of science, argues that we need to take far greater account of how "personal under-

standings" affect perceptions of risk. "Specific publics," he writes, "are likely to be skeptical, critical, or simply hostile to scientific statements—often because such statements seem to emerge from an idealized and inappropriate model of real world conditions."[2] This book argues that new, and more sophisticated, methods for understanding risk and the perception of risk (such as Wynne's) are required in the case of biotechnology. We need to understand, in particular, the complex relationships between "experts" and the "public," how knowledge circulates between them, and even how a clear distinction between these two domains might be breaking down (through movements such as citizen science and Do-It-Yourself Bio, for instance). Using biotech wisely, carefully, and productively requires better ways of understanding and measuring risk.

: : :

These five themes suggest how this book can also be read as an intervention into the debates about biotechnology. They show how and where we can make progress towards creative, productive, safe, and socially responsible uses of biotechnology.

FURTHER READING

There are several other books that have attempted to give more or less comprehensive accounts of biotechnology. The most thorough historical overview of biotechnology is Robert Bud, *The Uses of Life: A History of Biotechnology* (Cambridge: Cambridge University Press, 1994). This work focuses on manifestations of biotechnology before the 1970s, although there is some attention to more recent developments too. For an introduction to the science of biotechnology, the best places to start are W. T. Godbey, *An Introduction to Biotechnology: The Science, Technology, and Medical Applications* (Cambridge: Woodhead Publishing, 2014) and Ashim K. Chakravarty, *Introduction to Biotechnology* (New Delhi: Oxford University Press, 2013). These provide many more technical details than will be given here. Biotechnology is changing rapidly so technical books, in particular, may quickly be out of date.

There are several monographs that take up cultural and philosophical approaches to biotechnology: Jon Turney, *Frankenstein's Footsteps: Science, Genetics, and Popular Culture* (New Haven, CT: Yale University Press, 1998), Gregory Stock, *Redesigning Humans: Choosing Our Genes, Changing Our Future* (Boston: Mariner Books, 2003), and Robert Carlson, *Biology Is Technology: The Promise, Peril, and New Business of Engineering Life* (Cambridge,

2. Alan Irwin and Brian Wynne, eds., *Misunderstanding Science: The Public Reconstruction of Science and Technology* (Cambridge: Cambridge University Press, 1996), 9.

MA: Harvard University Press, 2011). These provide accounts of the relationship between biotechnology and culture, the impact of genetically engineering humans, and biological engineering, respectively. This is by no means a complete list of books about biotechnology, but these are good places to start if you are looking for a broad scope.

The various frameworks mentioned in this introduction derive from important scholars in the field of science and technology studies. The notion of coproduction comes from the work of Sheila Jasanoff, *States of Knowledge: The Co-Production of Science and the Social Order* (New York: Routledge, 2004). The story of Robert Moses and his bridges can be found in Langdon Winner, "Do Artifacts Have Politics?" *Daedalus* 109, no. 1 (1980): 121–136. Winner is arguing that technologies (including seemingly mundane, everyday objects) are not politically neutral—they are designed in particular ways and used in particular ways that have social and cultural effects and that therefore they are political. However, see also the arguments of Bernward Joerges, "Do Politics Have Artefacts?" *Social Studies of Science* 29, no. 3 (1999): 411–431.

The notion of plasticity in biotech has been discussed by Hannah Landecker, "Living Differently in Time: Plasticity, Temporality, and Cellular Biotechnologies," *Culture Machine* 7 (2005). There is a significant literature that addresses the theme of promise in biotech in various ways. For anthropology this is summarized in Karen Sue-Taussig, Klaus Hoeyer, and Stefan Helmreich, "The Anthropology of Potentiality in Biomedicine," *Current Anthropology* 54, no. S7 (2013): S3–S14. Particularly worthy of mention are Nik Brown, Alison Kraft, and Paul Martin, "The Promissory Pasts of Blood Stem Cells," *Biosocieties* 1, no. 3 (2006): 329–348, and Michael Fortun, *Promising Genomics: Iceland and deCODE Genetics in a World of Speculation* (Berkeley: University of California Press, 2008).

Finally, the arguments of Brian Wynne are laid out in numerous places, but the best place to begin is Brian Wynne and Alan Irwin, eds., *Misunderstanding Science? The Public Reconstruction of Science and Technology* (Cambridge: Cambridge University Press, 2004). Another, related, approach to the public understanding of science can be found in Helga Nowotny, Peter Scott, and Michael T. Gibbons, *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty* (Cambridge: Polity, 2001).