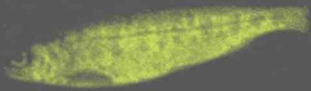

# ENGINEERING TROUBLE

## IOTECHNOLOGY AND ITS DISCONTENTS

ited by Rachel A. Schurman and Dennis Doyle Takahashi Kelso

# Engineering Trouble

*Biotechnology and Its Discontents*

EDITED BY

Rachel A. Schurman

AND

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UNIVERSITY OF CALIFORNIA PRESS

*Berkeley Los Angeles London*

University of California Press
Berkeley and Los Angeles, California

University of California Press, Ltd.
London, England



Library of Congress Cataloging-in-Publication Data
Engineering trouble : biotechnology and its discontents / edited
by Rachel A. Schurman and Dennis Doyle Takahashi Kelso.
p. cm.
Includes bibliographical references and index.
ISBN 0-520-23761-7 (cloth)
ISBN 0-520-24007-3 (paper)
1. Genetic engineering—Social aspects.
2. Agricultural biotechnology—Social aspects.
3. Food—Biotechnology—Social aspects.
I. Schurman, Rachel. II. Kelso, Dennis D.
TP248.6.R4645 2003
306.4'6—dc21 2002152991

Manufactured in the United States of America
13 12 11 10 09 08 07 06 05 04
10 9 8 7 6 5 4 3 2 1

The paper used in this publication is both acid-free and totally chlorine-free (TCF).
It meets the minimum requirements of ANSI/NISO Z39.48-1992 (R 1997) ⊗

# ACKNOWLEDGMENTS

This book emerged out of a reading group on biotechnology started in 1997 by several of the contributors. At the time, a number of us were based in the Energy and Resources Group (ERG) at the University of California, Berkeley, a place where faculty and students are encouraged to pursue new ideas, eclectic thinking, and socially and environmentally significant research questions. We thank our friends and colleagues both in ERG and in the larger Berkeley community for stimulating the research that ultimately led to this book. We also thank the director of the Institute for International Studies at Berkeley, Michael J. Watts, and Professor Steven Weber for channeling key institutional and financial support to this project, ensuring that we would have the facilities (both physical and financial) to continue working collectively on this book, even after most of the original members had moved on to new cities and occupations. Funds for the project were kindly provided by the John D. and Catherine T. MacArthur Foundation through a grant to the Institute for International Studies at UC Berkeley titled "Globalization and the Rethinking of International Security: Problems of Multilateral Governance and Identity Politics."

The coeditors also thank their current departments, the Department of Sociology at the University of Illinois and the Environmental Studies Department at the University of California, Santa Cruz, for offering supportive environments in which to work. Rachel Schurman gratefully acknowledges the Department of Sociology and the Center for Advanced Study at the University of Illinois, and the Yale Program in Agrarian Studies, for providing her with critical release time to work on this book. In addition, the Program in Agrarian Studies at Yale provided a wonderful place to read, think, and write in a warm and congenial atmosphere.

Several other people also made important contributions to this project.

Emin Adas at the University of Illinois provided essential research and computer assistance during the manuscript preparation, particularly in the last stages as the manuscript was going to the University of California Press. Anne Kapuscinski at the University of Minnesota was there all along (in spirit if not in body) with words of encouragement, insightful comments on several of the chapters, and useful explanations on the science side of things. In putting together this volume, we had the opportunity to work with a superb editorial team at the University of California Press. Blake Edgar showed great interest and enthusiasm for the project from our first contact and has remained a committed and congenial editor with whom to work. Nicole Stephenson, who assisted Blake during the initial stages of this project, was also helpful in many ways. Erika Büky skillfully guided the revision of the text; and she made significant contributions to both the substance and clarity of the book. Carlotta Shearson, our heroic copyeditor, improved the chapters on many levels. The book reflects her ability to expose and correct weaknesses in content as well as expression, and we are grateful for her hard work, engagement, and patience. Finally, we wish to thank the reviewers who provided valuable comments on an early version of the manuscript. Philip Bereano, William Lacy, and Philip McMichael brought to the task a rich blend of experience and scholarship; we very much appreciate their contributions to our thinking. Of course, any remaining errors or other shortcomings in this volume are our own. Robert Devlin at the West Vancouver Laboratory of Fisheries and Oceans Canada, with characteristic generosity, allowed us to use his photograph of transgenic and nontransgenic coho salmon in the design of the cover. To all, we offer our sincere thanks.

Finally, we wish to acknowledge the more personal debts that made this book possible. We are grateful for Michael Goldman's close reading of a number of chapters, his able assistance with the title, and his positive outlook on life and wonderful sense of humor. William Munro played a key role as an editor, a sounding board, and a good friend. Migahm Takahashi-Kelso not only endured her spouse's long absences for field travel but also served as an enthusiastic proponent, thoughtful discussant, and critical reader. And, of course, heartfelt thanks go to our loving and supportive families, who are always there when we need them for emotional and gastronomic sustenance.

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# Biotechnology in the New Millennium

## *Technological Change, Institutional Change, and Political Struggle*

*Rachel A. Schurman*

In September 2000, the business section of the *New York Times* ran a front-page story about a new problem in the nation's food supply. A new genetically engineered (GE) corn containing the protein Cry9C had been found in several nationally sold brands of corn tacos (Pollack 2000).[1] Although the corn, known as StarLink, had been approved for use in animal feed and in industry, it had not been approved for human consumption. Yet when a group of social activists hired an Iowa-based company to test the tacos, there it was.

What seemed at first to be just another bump in the history of biotechnology turned out to have enormous repercussions. In addition to ending up in the U.S. food supply, where it wreaked havoc, the genetically engineered corn found its way into the food systems of many other countries in which it had also not been approved. Tensions over trade in GE agricultural products flared, and key U.S. agricultural importers, such as Japan and South Korea, began rejecting shipments of U.S. corn on the grounds that they were contaminated with StarLink. When U.S. agricultural importers began to seek non-GE sources of corn from such countries as Brazil and China, U.S. farmers and the U.S. Department of Agriculture (USDA) panicked about the major market losses that would inevitably result.

In the U.S. heartland, where most of the corn had been grown, the contamination problem exploded in another way. The company that produced the seed, Aventis CropScience, tried to blame farmers for not following proper planting procedures and not taking adequate care to keep StarLink corn separate from their conventionally grown crops. Angered and offended, farmers charged that the company had not properly informed them about how to raise and segregate the corn. Both groups were deeply concerned about the liability for losses associated with StarLink. The incident created a rift between these formerly friendly business partners and revealed differences in their interests in and positions on the technology, differences that had not been previously apparent.

Some five months after the unapproved corn was first detected, the USDA agreed to spend up to $20 million to buy back the remaining StarLink corn seed from seed companies. The Bush administration's rationale for the buyback was that the debacle was in part the fault of the U.S. Environmental Protection Agency (EPA), which had agreed to a two-tiered system of regulation on the assumption that GE corn could be grown for animals and kept out of the human food supply (Kaufman 2001a). Despite the administration's efforts to resolve the crisis, reverberations from the StarLink incident were felt long after the problem was identified. In the end, food manufacturers recalled nearly three hundred products, U.S. corn trade with many foreign countries was seriously disrupted, and the industry paid more than $10 million to farmers in Iowa alone (Lin, Price, and Allen 2001, 40, 46-47; Perkins 2001, 8). In March 2002, a federal judge settled a class action lawsuit, brought by consumers who complained of allergic reactions to StarLink corn, with an award of $9 million (Robinson 2002). But perhaps most significantly, the StarLink incident moved agricultural biotechnology squarely into public view.

In many ways, the StarLink corn incident is emblematic of the political, economic, and institutional crises that have befallen agricultural biotechnology at the beginning of the twenty-first century. As we move into the new millennium, agricultural biotechnology—that is, the use of recombinant DNA techniques in food, feed, and raw materials—faces a highly uncertain future.[2] Although there is little doubt that biotechnology as an industrial production complex, a set of material techniques and practices, a cultural icon, and a bundle of social relations is here to stay,[3] the directions in which the technology is likely to go, the extent to which it will become part of our daily lives, the uses to which it will be put, and the political and institutional environment in which it will evolve are more uncertain now than at any time since the early 1980s. Indeed, we appear to be standing at a crucial juncture in the history of the technology, a juncture at which the future is surprisingly open to the actions of a broad range of (human and nonhuman) actors.

Although the StarLink incident can be seen as the high-water mark in the contemporary crisis of agricultural biotechnology, the causes of the crisis are complex and involve deep tensions that have been brewing for decades. These tensions reflect a clash of worldviews about whether such a potentially revolutionary technology should be introduced into the socionatural world at all; who should have the power to decide; what kinds of precautions should be taken to limit the harm that is done to people and the environment; and what kinds of institutional structures should be established to control and regulate these technologies. As a geared-up and heavily invested (in all senses of the word) life sciences industry has moved forward with its technoscientific interventions in virtually every form of life, many have started to challenge the assumption that any one segment of society should have such a prerogative. These challenges have made genetic engineering into one of the most contested technologies of our time.

While social resistance is one source of uncertainty for the biotechnology industry, farmers, food retailers, and policymakers represent another. Will farmers continue to find a market for their products if they use these increasingly controversial technologies on their farms and in their dairies and fish pens? If farmers opt not to use the technology, will they be adversely affected by genetic "contamination" from pollen drift or other sources of genetic change or by the presence of trace amounts of genetically engineered organisms (GEOs) in the food supply chain? Will retailers lose customers by allying themselves with the biotechnology industry instead of with some of their most vocal and concerned consumers? Even government regulators are unsure how to deal with the political sensitivity of these new technologies. Should regulatory agencies continue to facilitate their commercialization, or should they respond to that portion of the public that advocates that we proceed with greater caution? Different groups are clearly worried about different issues, but all contribute to a growing uncertainty about biotechnology at the beginning of the millennium.

One of this book's primary goals is to illuminate the dynamics of this key historical moment, including the concrete political-economic changes taking place in and around the biotechnology sector, the institutional foundations on which those changes have been built, and the political struggles they are generating. Ten to fifteen years ago, a spate of studies predicted a number of important social, economic, political, and environmental changes that would occur as the science and industry of biotechnology developed. These changes included the emergence of a new and closer relationship between industry and universities (Busch et al. 1991; Kenney 1986; Kloppenburg 1988); the erosion of biodiversity (Fowler and Mooney 1990); growing social and economic inequalities associated with the patenting and use of these new technologies (Busch et al. 1991; Doyle 1985; Juma 1989); and their potentially adverse environmental consequences for ecosystems (Goldburg et al. 1990; Krimsky and Wrubel 1996; Rissler and Mellon 1996). Although the industry was still young at the time of these studies,[4] they pointed to the way in which biotechnology was leading to greater economic concentration in the agro-food sector (Busch et al. 1991; Buttel, Kenney, and Kloppenburg 1985; Hobbelink 1991; Kenney 1986); to the privatization and commodification of plant genetic resources and other life forms (Kloppenburg and Kenney 1984; Kloppenburg 1988); and to the further extension of capitalist production relations into the farm sector (Goodman, Sorj, and Wilkinson

1987). The best of these studies took a historical approach to these issues but also identified what was new about the new biotechnologies.

Although this body of literature proved prescient in identifying some of the critical changes biotechnology would introduce into society, the biophysical world, and the global agro-food system, three important new developments call for a fresh look and additional analysis. First, the technology has moved from the lab to the field—or more accurately, from the lab to the field, the barn, the forest plantation, the sea, and the human body.[5] Between 1996 and 2001, the number of acres planted with GE crops—almost exclusively corn, soy, canola, and cotton—rose from an estimated 1.7 million to an estimated 130 million worldwide (James 2001, 1). Genetic-engineering techniques are also being applied to a growing number of life forms, including insects, farm animals, marine organisms, trees, and humans. Perhaps more important, technology development has been revolutionized—and greatly accelerated—by the advent of genomics and the synergies that have emerged between molecular biology, recombinant DNA techniques, and the bioinformatics sector (see Pueppke 2001; Boyd, this volume; Scholz, this volume).

The second major development has been the extraordinary politicization of the technology. Just when the science and industry of biotechnology began to take off, the technology became a lightning rod for local, national, and transnational conflicts over trade, agriculture, and the environment. These conflicts and the political struggles they have engendered are transforming public perceptions (perhaps most importantly, among investors and consumers) of biotechnology's significance, promise, and future and have shaken the industry to its core.

The evolution of biotechnology, and the public's reaction to it, have strained existing social, economic, legal, and political institutions and revealed critical inadequacies in their ability to cope with the wide array of challenges posed by the technology. These processes are creating powerful demands for institutional change by specific parties and sets of interests. Thus the third major development has been institutional: as such weaknesses and problems are revealed, new institutional arrangements within and among societies—ranging from new food-testing systems to new international regulatory regimes governing trade in GEOs—are being created. These arrangements are changing norms and relations within the sector and are likely to have ramifications that extend far beyond it.

These developments raise many interesting questions, a number of which we seek to explore in this book. How has the biotechnology revolution actually affected the way we produce our food and raw materials? Has it altered the structure and organization of the agro-food sector and the power relations within it? What new social relationships have been forged as a result of the technology? There are also important questions about the institutional changes provoked by genetic engineering. What concrete institutional reforms have been associated with the technology? What are the dynamics of institutional change, and what political struggles are those dynamics engendering? What regulatory structures are becoming dominant within the emerging institutional matrix, and what groups and interests will they favor and empower? How will these new institutions shape the way we relate to the technology in the future?

We also need to understand better the politicization of the technology. What does this politicization mean, what are its consequences, and what is behind it? How broad-based is social resistance to biotechnology? Is this resistance confined to a handful of activist groups and organizations, or are we facing a rapidly expanding popular movement against the technology? How is the politicization of biotechnology influencing the trajectory of technological change? Although the number of academic and popular books being published on biotechnology has burgeoned, none has seriously explored these questions. It is this gap that the present collection seeks to fill.[6]

## TECHNOLOGICAL CHANGE

When the first wave of political-economic analyses of agricultural biotechnology appeared in the 1980s, the commercial application of modern biotechnology was still in its infancy. The technology clearly held the potential to transform the agriculture, food, human and animal health, and pharmaceutical sectors, but little technology had actually moved from university and industry laboratories into the commercial sphere. During the 1990s, however, that situation changed dramatically, as a large number of agricultural biotechnology applications were approved for use in the United States as well as abroad.[7]

The two most extensively deployed biotechnologies have been those that render plants resistant to pests and those that confer herbicide tolerance to crops (Shoemaker 2001). Indeed, between 1996 and 1999, herbicide-tolerant soybeans were adopted more rapidly than any agricultural technology in the world, with pest-resistant corn not far behind (Buttel, this volume). Reflecting U.S. farmers' embrace of the technology, in the year 2001, an estimated 68 percent of the U.S. soybean crop, 25 percent of the U.S. corn crop, and 69 percent of the cotton crop were planted with genetically engineered varieties (Agricultural Statistics Board 2001). Also successfully commercialized in the 1990s were chymosin, a genetically engineered enzyme used in cheese production (approved in 1990), and bovine somatotropin (approved in 1993), a genetically engineered growth hormone that causes cows to produce more milk. Because GEOs are widely used by the food-manufacturing industry, they have become virtually ubiquitous in processed food (Barboza 2001a).

Although the adoption of GE crops has been extraordinarily rapid in the U.S., they have not spread around the world as fast or as widely as some of their proponents suggest.[8] Indeed, although farmers in about a dozen countries legally planted GE corn, soy, canola, and cotton (the four most important transgenic crops) in 2001, the use of genetically engineered seeds remains heavily concentrated in only three countries: the United States, Canada, and Argentina. Together these countries account for more than 95 percent of the transgenic acreage planted worldwide. (When China is added, this figure rises to 99 percent; see James 2001.)[9]

Although it is mainly plant biotechnologies that have become a commercial reality in the last decade, molecular biologists and the biotechnology industry have applied their energies and resources to a broad spectrum of living organisms.[10] Currently, scientists are genetically engineering animals for better disease resistance, faster growth, more attractive market traits (e.g., leaner meat or more meat), and higher-protein milk.[11] Some animals—referred to as "pharm animals"—are being genetically engineered so that they can be used to produce body parts for humans and various human therapeutics (e.g., drugs or proteins) in their milk and tissues (Royal Society 2001; Yoon 2000b). Industry researchers are genetically modifying salmon to make them grow faster, and trees to improve market qualities (see the chapters by Dennis Kelso and Scott Prudham in this volume). Even insects have not escaped the molecular biologist's gaze: silk moth caterpillars are being genetically engineered to produce stronger silk, male bollworm moths to render sterile the bollworm moth population in the southern United States, and mosquitoes to deliver vaccines to humans and livestock (Kilman 2001). Although none of these applications has been approved by the relevant government authorities and made it to the marketplace, much of this applied research is quite advanced, and some firms are now seeking regulatory approval for their organisms (e.g., transgenic salmon).[12]

### *The Growth and Consolidation of the Biotechnology Industry*

With the commercial deployment of the technology have come important changes in the size, significance, and structure of the industry. Economically insignificant twenty years ago, the biotechnology industry has become a leading sector in the economy. In the United States alone, the industry generated $20 billion in revenues in 1999, of which agriculture accounted for $2.3 billion (Ernst & Young 2000).[13] And these data include only U.S. companies that are *primarily* engaged in biotechnology activities. The inclusion of industries that provide inputs to the biotechnology sector or utilize the new techniques to produce their products would undoubtedly raise this figure much higher.

Martin Kenney (1998) describes the industrial complex that has grown up around biotechnology as a "new economic space." This space has come to be populated by a handful of life sciences firms, most of which were formerly part of the chemical industry. Although early analysts (see especially Doyle 1985; Hobbelink 1991) clearly perceived the trend toward concentration, William Boyd (this volume) documents the breadth of the structural changes that have occurred as the industry, the technology, and the legal system have coevolved. In recent years, the life sciences firms have integrated vertically and horizontally and now encompass much of the commodity supply chain, from chemical inputs to seed companies to farming (in the form of production contracts). A study by Nicholas Kalaitzandonakes and Bruce Bjornson underscores the degree of concentration that has occurred: during the first half of the 1990s, there were some eight hundred mergers, acquisitions, and other strategic alliances in the agricultural input industry. There were only about a fifth as many a decade earlier (the study is cited in Shoemaker 2001).

Underlying this dramatic shift in industry organization has been the emergence of stronger intellectual-property protection for life forms. In the 1980s and 1990s, patent protection was broadened to include whole plants as well as their constituent parts (genes, gene fragments, proteins, and seeds). Patent rights were also extended, under certain circumstances, to DNA sequences. As the courts extended property rights deeper and deeper into the biological sphere, they created a powerful incentive for industry expansion (Boyd, this volume).

There have also been changes in the nature of competition in the industry (Boyd, this volume; Goldsmith 2001). These changes appear to have been driven by several factors—changes in property law, the fact that a handful of firms control the major segment of the industry, and the emergence of the fields of genomics, bioinformatics, and, most recently, proteomics. According to William Boyd's analysis, the gigantic firms that dominate the life sciences industry now compete by amassing huge property portfolios in the form of patented transgenic organisms, their constituent parts, and the technologies used to create them (see Ratner 1998; Service 2001). Although the industry's use of blocking patents is not new, the application of this competitive strategy to life forms is. The cost of researching and developing new traits and organisms, soliciting patents and regulatory approval, paying licensing fees, and marketing new products has risen so high that few firms can afford to enter the industry.

## *The Waves of the Future*

If the large-scale investments that the private and public sectors are making in these areas are any indication, genomics, bioinformatics, and proteomics are clearly the wave of the future.[14] *Genomics* is the automated sequencing and analysis of genes; *bioinformatics* refers to the inference of genes' functions from information about known DNA sequences in other organisms;

and *proteomics* refers to the science of protein functions and their relationship to genes. All three rely heavily on the new information technologies. The emergence of these new sciences, and their incorporation into plant and animal genetic-engineering research, have raised even higher the barriers to entry that characterize the agricultural biotechnology industry.

William Boyd and Astrid Scholz (both in this volume) argue that genomics has become the driving force of innovation in the biotechnology industry, altering research agendas and augmenting competition over intellectual property rights. These new sciences promise tremendous acceleration of product research and development (R&D)—an all-important attribute in a field in which speed is the essence of competition. Indeed, the language of speed, racing, and getting there first are pervasive in corporate discussions and in descriptions of the industry.[15] Genomics and bioinformatics have enabled firms to analyze many more organisms and traits at a much lower cost, greatly augmenting the number of patents for which firms can apply. The cost of "going genomic," however, is high, which is why most life sciences firms have entered into partnerships, joint ventures, and other strategic relationships with specialized genomics and bioinformatics firms (Boyd, this volume).

The development of these new information sciences has had other consequences as well. The pharmaceutical industry's embrace of these new technologies in its drug discovery process over the last decade has had important implications for the industry's uses of genetic resources from the global South.[16] As Astrid Scholz shows in this volume, the technological changes that have swept the industry have pushed the pharmaceutical sector toward combinatorial chemistry and "rational" drug design, reducing the economic significance of natural products. As a result, the balance of power in genetic-resource negotiations has shifted even further toward pharmaceutical firms, which can now credibly claim that they are less in need of the South's genetic resources. In the future, this reduced dependence is likely to limit the economic benefits Southern countries can derive from their biological diversity.

## THE NEW BIOTECHNOLOGY POLITICS

The spread of biotechnology; the consolidation of the biotechnology, seed, chemical, and pharmaceutical companies into a powerful life sciences industry; and the rush to patent genetic organisms and other constituent building blocks of life have all contributed to the recent politicization of the technology, an occurrence that none of the literature predicted. Indeed, the past five years have seen an immense escalation in political activity focused on the use of genetic engineering in agriculture. This activity is starting to shape the development of the technology and may affect it even more in the future. Any attempt to theorize the process of technological change must take this important influence into account.

An interesting question to ponder is why none of the scholars and analysts of biotechnology anticipated either the depth and power of the social response to the technology's development and deployment, or the political, economic, regulatory, and institutional crises this response would precipitate as the century came to a close. In similar fashion, the literature has also glossed over the real scientific challenges—what Andrew Pickering (1995) would call the "resistances of nature"—that have accompanied efforts to genetically engineer specific plants, animals, and marine organisms. Addressing the resistances of nature, although we do not do so here, is a critical next step for agro-food studies, as David Goodman persuasively argues in this volume.

### *Sources of Resistance*

Although the most serious political challenges to the biotechnology industry have come in the past several years, social tensions about the new biotechnologies are neither new nor isolated from other social issues and conflicts (McAfee, this volume). Ever since it became common knowledge that scientists *could* transfer genes across species in ways that were unlikely to occur in nature, individuals and groups have publicly questioned whether they (or we) *should* be doing so. Indeed, a close look at the North American antibiotechnology movement suggests that it has been around nearly as long as the technology.

Social resistance to the use of genetic engineering in agriculture has come from many quarters and is rooted in a broad array of moral, cultural, material, health, and environmental concerns. In Western Europe, where antibiotechnology activism has been most intense, sustained, and effective, activists' critiques have centered on the health and environmental implications of GEOs and the metabolic threats they represent to the living land and the living body (Goodman 1999; Schurman and Munro, this volume). Derrick Purdue's analysis shows how European groups mounted a powerful challenge to biotechnology in the mid-1990s, a challenge based on the mobilization of "counterexpertise" that combined "a situated knowledge of seed science and law with impressive political skills" (Purdue 2000, 11). Coterminous with other food and health scares such as mad cow disease and a growing anti-imperialist (and anti-American) sentiment, public opposition to biotechnology in many European Union (EU) countries has united consumers, farmers, environmentalists, and others in a fierce rejection of the technology and its purveyors. Social activists, particularly the environmental activists, have been instrumental in mobilizing this public opposition to biotechnology—most importantly, among consumers—by tapping into deeply held cultural and aesthetic values with respect to food