Designs on Nature

Science and Democracy in Europe and the United States

Sheila Jasanoff

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Unsettled Settlements

Between 1975 and 1995, biotechnology moved from a research enterprise that left even its most committed practitioners unsure of themselves to a global industry promising revolutionary benefits in return for allegedly well-understood and manageable risks. This shift occurred almost simultaneously and with remarkable speed throughout Europe and North America (see appendix). To facilitate commercialization, the United States, Britain, and Germany—and the European Community (later the EU)—all adapted their laws and regulations to control both laboratory research with genetically modified organisms and their planned, or in official language "deliberate," releases into the environment. Within barely a decade, environmental consequences that were once considered speculative and impossible to assess came to be regarded within policy circles as amenable to rational, scientific evaluation. By 1990 it appeared that, for genetically modified crops, apocalyptic visions and the rhetoric of science fiction could be set aside in favor of objective expert discourses and routine bureaucratic approvals.

These changes in the status of agricultural biotechnology were all the more unexpected because, at the time of commercialization, the risks of industrial-scale application remained largely hypothetical. Scientists and companies seemed confident that no serious harm would befall ecosystems or human health if corn and cotton crops were fitted out with herbicide- or insect-resistant genes, or if fruit farmers sprayed their orchards and berry plants with gene-deleted bacteria designed to prevent frost formation. Yet, unlike toxic chemicals, the products of the new biotechnology had not been in circulation long enough to manifest a wide range of beneficial or adverse effects. There was no storehouse of precedents that policymakers could reach

into for historically documented evidence concerning the widespread use of laboratory-crafted organisms. As regulators in different policy systems approved the environmental release of GMOs, they were therefore obliged to find other credible ways of demonstrating the technology's safety.

Scientific and administrative hurdles stood in the way. On the scientific side, regulators and researchers had to agree on what needed to be known for policy purposes—in other words, they had to produce a robust and relevant body of regulatory science.[1] On the administrative side, systems of oversight and management had to be constructed to provide regulators with expert guidance and assure the public that commercialization would take place under adequate supervision. Cross-national divergences soon appeared. We saw earlier that attempts to conceptualize the "problem of biotechnology" for policy purposes initially led to three different interpretive frames in the United States, Europe, Britain, and Germany: as a collection of *products*, as a potentially hazardous technological *process*, and as a threatening *program* of state-sponsored control of society through technoscience. In this chapter we will see how these framing choices influenced the scientific practices, assessment principles, and management structures that each nation developed for releasing GMOs into the environment—and why, in each case, national efforts failed to silence further controversy.

The chapter, then, tells two stories. The first is that of normalization, a common theme in modernity. Vague, unnamed, and unbounded fears were specified and made tractable, or so it seemed, through evolving systems of framing, classification, calculation, and control. Producing a new state of technologically improved, or designed, nature demanded heroic efforts of legitimation on the part of scientists, producers, and regulatory institutions. To see how these ordering mechanisms were put together, we need to step back and examine the particular kinds of disorder that the proponents of biotechnology in each country were trying to discipline and control. We therefore begin with vignettes of three national controversies involving the deliberate release of GMOs. The manner in which they were framed reflected, and in a sense reaffirmed, each nation's particular style of controlling risk. In the United States, regulators claimed the authority of science to support their conclusions with regard to product safety; in Britain, by contrast, regulators relied on the more embodied concept of expert judgment to certify the safety of GM as a process; and in Germany, legitimacy was sought through targeted institutional and procedural reforms establishing new forms of dialogue between citizens and the programmatic state. But it was the fragility of each accommodation that proved in the end to be most unexpected. By the late-1990s debates reopened on issues that industry and government hoped had been definitively laid to rest.

The second part of the chapter, then, deals with the less common story of *de*normalization. It gradually became clear in each country that the political

acceptability of agricultural biotechnology depends as much on the trustworthiness of the supporting social and institutional arrangements as on the abstractions of scientific risk assessment. New debates and controversies revealed different fault lines in the consensus on framing achieved through the first round of normalization. The actors, the locus of controversy, and the terms in which disagreements were expressed all diverged cross-nationally, calling attention to the intensely culture-bound character of technology's public acceptance. These conflicts, in turn, elicited further social and scientific experiments, which round out the chapter. I conclude by relating these developments to underlying theoretical issues of coproduction and the relations of science, state, and citizens.

The Greening of Biotechnology: Three Tales

Agricultural biotechnology has sought to establish its claim on public acceptance by explicitly distancing itself from the risky, dirty, polluting, and inefficient industries of the industrial era. It is a *green* technology, a point that industry ceaselessly documents in its web-based and televised promotional materials, as well as in glossy brochures and annual reports. These documents conjure up images of a fertile earth and its abundant fruits, often featuring sunny shots of families with young children. The theme of order is front and center: a favorite visual motif is unbroken rows of grain receding into the deep distance. The time lines frequently purveyed by biotech companies reconnect the agricultural enterprise to the remote past of human-nature interactions, untouched by the grime of the industrial revolution, and predating by millennia the controversial intrusion of modern reductionist science so deplored by the German Greens. For example, the Biotechnology Industry Organization (BIO)—a lobbying association of more than a thousand members formed in the late 1990s to press the cause of the agricultural and pharmaceutical sectors—lists the first three achievements of biotechnology as the brewing of beer by Sumerians in 1750 B.C., the use of moldy soybean curds as an antibiotic by the Chinese in 500 B.C., and the use of powdered chrysanthemum as an insecticide, again by the Chinese, in A.D. 100. Another BIO timeline starts off the march of biotechnology at 8000 B.C., with the first domestication of crops and livestock.[2]

This is wishful thinking carried to high art. It impresses pop culture into serving politics and merges advertising with history. To get people to believe in these representations, though, requires more than electronic handwaving, and not only media consultants and public relations firms but, more importantly, science and government have to play their part in securing public acceptance of promises of safety. The first phase of orchestrating the preconditions for the environmental release of GMOs produced its share of

discords as well as harmonies. These were articulated differently in the three national contexts. Their settlement drew on different traditions of enrolling science into decision making, as well as different procedural repertoires for building public trust. The resulting policies, too, were different, in ways that reflected local political circumstances. In turn, these early ordering moves laid the foundations for future expressions of uncertainty and discontent.

United States: Science Speaks

The operative term driving U.S. politics on GMOs was risk, but that small word marks more the beginning than the endpoint of analysis. When the German sociologist Ulrich Beck wrote his highly influential monograph *Risk Society*,[3] he imagined risk as a transforming force reshaping social relations throughout the industrial world. People everywhere, Beck argued, were at risk from their own creative powers, materially transformed into hazardous technologies, and these risks could strike one down regardless of one's social or economic standing. Class in the traditional sense offered no defenses against, for example, the ozone hole, climate change, or nuclear catastrophe; the proliferation of risk created its own moral classifications of the potentially damned and the potentially saved. In U.S. social science and policy analysis, however, risk had in the 1980s as now a different flavor from risk as conceptualized in European social thought. If the world's most powerful nation saw itself as a "risk society" at all, it was only as a prelude to controlling yet better the threats resulting from novel methods of production. Not for U.S. decision makers was a sociological account that portrayed people as helpless victims of their own inventions.

Taming risks, however, requires work.[4] Who does this work and by what rules of the game? The answers, we have seen, were not fixed in U.S. law or policy when new GMOs were first readied for release into the environment. Indeed, GM techniques and the regulations authorizing their use evolved almost in unison during the late 1970s and early 1980s. In 1976, for example, the National Institutes of Health issued the first guidelines for recombinant DNA research. A year later, Steven Lindow, a graduate student at the University of Wisconsin, discovered that a mutant strain of the bacterium *Pseudomonas syringae* could inhibit frost formation on plants.[5] That year, 1977, some sixteen bills to regulate rDNA research were unsuccessfully introduced in the U.S. Congress. Vehemently opposed by both science and industry, federal legislation never materialized, and supervision of genetic research continued to rest in the hands of a grant-making agency—NIH—while the results of that research moved ever closer to the commercial market.

By the early 1980s Lindow, by then at the University of California, Berkeley, had refined his discoveries and was ready to test them outside the laboratory. His team had identified the gene responsible for producing an

ice-nucleating protein in the "normal" strain of the *P. syringae* bacterium, called the "ice-plus" strain, and found a means of deleting this gene to create a frost-inhibiting "ice-minus" strain. The Berkeley researchers, including Lindow and his colleague Nikolaos Panopoulos, were now ready to shift their attention from engineering bacteria to engineering the conditions—both natural and social—for their deployment in the environment. Spraying the gene-deleted ice-minus bacterium on plants, they hypothesized, would displace the naturally occurring bacterial population and raise the frost resistance of the treated plants. It remained only to get official sanction to field-test their idea, and the institution from which these university researchers could most naturally seek approval was NIH.

From the researchers' standpoint, each step they took followed routinely from the one before, in a normal progression from basic research to product testing. From the standpoint of the social reception of these events, however, the Lindow-Panopoulos initiative, and equivalent moves by industry, breached several important institutional and conceptual boundaries and posed unprecedented problems. These boundary-crossings became progressively more unmanageable. The process began quietly enough with NIH's Recombinant DNA Advisory Committee, which was formally responsible for reviewing the application. NIH advisers had satisfied themselves by this time that the fears expressed at the 1975 Asilomar conference had been groundless, including even worries about GMO releases into the environment. Single gene deletion was too specific an intervention, its likely results too predictable, to occasion much eyebrow-raising among researchers using rDNA techniques. RAC approval, with scientists passing judgment on other scientists, was therefore unsurprising. But as we saw in chapter 2, review by disciplinary peers alone did not satisfy what opponents claimed was a legal mandate: the need to conduct a public environmental assessment under the National Environmental Policy Act. The ensuing litigation, which led to a decision in favor of the plaintiffs,[6] established that expert deliberations, however open and thorough, were no substitute for the public review of NIH's risk assessment principles contemplated by NEPA.

In taking the ice-minus bacteria from the lab to the field, researchers crossed more than the line between peer-reviewed basic science and its regulated applications. They also moved from a world of controlled experiment (science) to a world of messy experience (agriculture), from technical discourse to political debate, and from the relatively sheltered preserves of academic science to a space of higher economic stakes and public scrutiny.[7] Alliances, tactics, modes of expression and of action all changed as the context for assessing the scientists' work shifted. Disagreement, which thus far had been contained within professional circles, spilled into less rule-bound channels. The Berkeley team eventually gained the federal approval it had asked for, but the community of Tulelake, California, where the test was to be

conducted, staged protests. An initial planting of three thousand treated potato plants was vandalized, although the trial was later repeated without opposition.[8] Controversy continued with the discovery that Advanced Genetic Sciences (AGS), an Oakland-based private company that had funded Lindow, had released the frost-preventing bacteria without proper authorization in a roof-top experiment on its own premises. Subsequently, AGS sought and received approval from the U.S. Environmental Protection Agency to conduct a study similar to Lindow's using strawberry plants. Legal maneuvers by Jeremy Rifkin and his associates to block the AGS test failed. Vandals destroyed much of the AGS site in April 1987, but in May company scientists dressed in eye-catching hazardous materials suits went forward with the intended release, earning predictable coverage from the national press.[9]

Some interpreted these events as the expected growing pains of a nascent technology. Popular anxiety, on this account, simply reflected the novel, unknown, and "dread" character of genetic engineering—attributes that social psychologists at the time commonly associated with elevated levels of public concern.[10] Things predictably grew calmer, on this same account, as communities became more familiar with genetic engineering, courts ceased encouraging irresponsible figures like Rifkin, and the media stopped retailing highly colored stories of improbable hazards. All these normalizing moves brought public perception back in line with the rational risk calculations made by experts; better information and more exposure acted as antidotes to the "sociology of error," that is, to collective responses based on a wrong assessment of the facts. The decrease in controversy "proved"—with only minor hiccups along the way—what scientists had claimed all along: that genetic engineering of crops and plants was safe, and would be seen to be so. Once conflict died down, the U.S. regulatory scheme for agricultural biotechnology came to be seen by many, especially within the United States, as a model of how scientific judgment could tame the uncertainties of technological innovation.

There are three problems with this happy reading of the ice-minus story, all of which loom as significant in the light of later events in the United States and Europe. First, the apparent closure of controversy was achieved in a period of American deregulation that reduced the type and intensity of scrutiny given to products of agricultural biotechnology. By early 1987, for example, RAC had decided to relax a number of restrictions to make studies like Lindow's significantly easier to conduct: RAC would not review tests already approved by other federal agencies, demand preauthorization of field tests for gene-deleted microorganisms, or require physical containment for organisms determined to pose low risk.[11] For the moment, regulators in and outside the United States interpreted this lowering of skeptical oversight as evidence that the research was acceptably safe, but the stability of this conclusion strongly depended on the credibility of the U.S. regulatory process as a

whole. *That* would prove in time to be less robust than biotechnology advocates had hoped.

Second, the field tests did not so much resolve the scientific questions as displace them—from the capacity of the bacteria to reduce ice nucleation under field-test conditions to their possible longer-term effects on the environment, which the field test by definition could not assess. EPA imposed monitoring requirements to address the latter issue, but some denied the need for such studies, since the mutant ice-minus strain exists in nature and is therefore a "known" entity with respect to its biological properties. Henry Miller, a former official of the Food and Drug Administration (FDA) and research fellow at the conservative Hoover Institution, as well as an outspoken foe of regulation, was especially caustic: "Even after EPA finally granted its approval for testing the 'ice-minus' microorganisms in the field, the agency conducted elaborate, expensive, intrusive—and predictably worthless—monitoring of the field trials. (Monitoring for what, one wonders—the harmless bacteria mutating into pit bulls?)"[12]

Miller's polemic papers over an important point: environmental release entailed questions that could not be answered by molecular biologists alone. The precision of gene splicing had seduced these scientists into believing that their manipulations were highly specific, and therefore wholly manageable, but molecular methods could not by themselves predict how the altered organisms would behave in an uncontrolled environment, such as an open field. An intellectual line of contestation was drawn between those (mostly molecular biologists) who insisted on the precision of genetic engineering as sufficient evidence of safety, and those (mostly ecologists) who saw the technique's application as introducing uncertainties that could not be resolved in the current state of knowledge.[13] The former viewed field testing as unnecessary so long as the GM construct involved no hazardous manipulation; the latter considered the field tests as essential in the scale-up of GM crops from lab to commercial production. The dispute between these two views remained alive, in and outside the United States, despite the best efforts of the proponents of biotechnology to quell it. Arguments that "science" had shown biotechnology products to be "safe" downplayed the fact that science did not speak with one voice on this issue.

The third point relates to the demand side of biotechnology. The ice-minus experiment did not prove to be a commercial success. Though Miller cites EPA regulation as the primary culprit, there were other compelling reasons. By the mid-1980s work was already underway on engineering pest resistance into plants, a technology that was to have, under the primary regulatory jurisdiction of the U.S. Department of Agriculture, wide commercial success with little of the hullabaloo produced by the ice-minus episode. Questions arose about whether the frost-resistant properties conferred by the ice-minus strain were significant enough to merit substantial economic investment.[14]

Biotechnology's success in the marketplace ultimately depended on demand, and in the United States, it was not ice-minus but genetically engineered, pest-resistant corn, cotton, and soybeans that eventually met the test of marketability.[15] These products targeted the needs of large-scale growers and catered to the safety concerns of these well-satisfied clients. Ignored in industry's calculus of expansion were many other actors who, at other times and in other places, would exercise their voice in the biotechnology debates: small farmers, organic producers, supermarkets, the food industry, environmentalists, consumers, and of course concerned biologists from multiple disciplinary backgrounds. The molecular biologists' perceptions of risk and safety proved in the long run too restrictive to meet the concerns of this heterogeneous, but interested, population.

Britain: Expertise Governs

Britain in the mid-1980s was a passive place for environmentalism. The British public displayed little of America's heightened concern for chemicals; even nuclear power ignited no protests comparable to those in Germany and the United States. Margaret Thatcher's Tory government scoffed at the perceived excesses of European green politics and remained unremittingly skeptical toward most claims of environmental degradation. Even the threat to the stratospheric ozone layer, discussed in U.S. scientific circles since the 1970s, was ignored at first by a prime minister who had been trained as a chemist. Her ministers adopted a no-nonsense, "show us the bodies" approach to scientific evidence, which was at odds with the more precautionary approach favored in other EC countries.

All this changed in the run-up to the 1988 British election, when a confident but also politically savvy Thatcher observed the rising green sentiment among the electorate and the aim of the Social and Liberal Democrats to turn the environment into a campaign issue. In a speech to the Royal Society on September 27, 1988, Thatcher surprised and pleased environmentalists by acknowledging that "we have unwittingly begun a massive experiment with the system of this planet itself."[16] Lecturing scientists on the need for better management and closer cooperation with industry, she also noted the need for more research on environmental issues. Follow-through was slow, but a year later the nomination of a new environment secretary, Christopher Patten (replacing the notably anti-environmental Nicholas Ridley), and the introduction of an omnibus "Green Bill" signaled some progress on the Conservatives' new environmental agenda.

Regulatory procedures for agricultural biotechnology were modified during this peaceful period, and they followed in the main British traditions of decisionmaking by experts. The first authorized releases of a genetically engineered microorganism in the United Kingdom illustrate the point. By the

late 1980s research on biological pest control, using a baculovirus as the vector, was underway at the Institute of Virology and Environmental Microbiology (IVEM) in Oxford, a unit of the Natural Environment Research Council (NERC). David Bishop, IVEM director from 1985 to 1995, was determined not to repeat the mistakes of his counterparts in the United States. He hoped to avoid the traps they had fallen into by proceeding in small, incremental steps, each time collecting data to enable the next move. Others, he suggested, had been less cautious: "A lot of research is like trying to run before learning to walk, before learning to crawl, before learning to focus your eyes."[17] In IVEM's case, one solution was to use an enfeebled strain of the baculovirus by removing the gene that produced its protective coat protein. The modified organism would be less persistent in the environment and would thereby pose a smaller risk of escaping the researchers' control.

Bishop was extremely sensitive to the public relations side of IVEM's research. Prior consultation with environmental groups, notices in local papers, and a video explaining the nature of the research were among the means he used to reassure the public about the baculovirus release planned for the spring of 1989. The strategy apparently worked at the time of the first field test. IVEM received only two written requests for more information, with no follow-up from the concerned citizens. Newspapers and magazines did not report the event, their silence starkly contrasting with the media blitz around Lindow and AGS on the other side of the Atlantic. Bishop's scientific colleagues more or less reluctantly admired his handling of a potentially controversial situation, some praising it as "exemplary,"[18] but others expressing annoyance at his self-promotion in making "such a [public] meal of it."[19]

Behind the business-as-usual façade, questions continued to swirl, but, like the test virus itself, these did not spill into the open. Field test applications were approved by the Health and Safety Executive, acting on advice from the Advisory Committee on Releases to the Environment. The government's mandate was limited to reviewing the safety of the field test; in turn, the test itself was designed to illuminate only the questions that ecologists deemed important for evaluating safety—the modified organism's survival, persistence, and dispersal, and possible gene flow between it and other populations. But could contained releases such as IVEM's offer reliable insights into large-scale commercial use, industry's ultimate goal? The Oxford experiments, after all, were conducted under rigorous containment conditions, none of which could be maintained during full-scale commercial application: an enfeebled GMO strain, prior testing with limited numbers of target species, use of physical barriers, attentive monitoring, and eventual disinfection of the test site. Given these discrepancies between the real world and field tests, environmentalists wondered whether testing might not convey a misleading impression of the safety of GMOs.[20] The government's experts, however, were not asked to wrestle with deeper questions about the tests'

correspondence to actual conditions of use—a problem that runs through all attempts to predict the efficacy of new technologies[21]—let alone to question the ultimate purposes of field testing particular organisms. Beneath the umbrella of expert reassurance, the seeds of doubt and uncertainty continued to germinate in secret.

Germany: Procedure Rules

In Germany 1990 was a watershed year for biotechnology. In that year, the German parliament passed a new genetic engineering law (Gentechnikgesetz, GenTG) and the EC adopted its two major Europe-wide biotechnology directives. Up to this time, German geneticists had operated, much like their American counterparts in the mid-1980s, under the supervision of an expert committee, the Central Commission for Biological Safety (Zentrale Kommission für die Biologische Sicherheit, ZKBS). Constituted in 1981, the twelve-member body was originally composed of eight biologists and, reflecting Germany's corporatist traditions, one representative each of unions, industry, environmental groups, and research organizations.[22] Its activities were conducted largely out of the public eye. The first commission report—a small, stapled-together, mimeographed booklet, clearly not intended for public consumption—was issued in 1988 and covered the twenty-six meetings held during the previous seven-year period.[23]

The political circumstances leading to the adoption of the GenTG ensured that the new law would have to grapple more seriously with questions of federalism and participation. The allocation of regulatory authority was a perennially sore point in a governmental system founded on a careful division of power between the center and the states (Länder). Participation, especially in technical decision making, was an increasingly salient theme in German politics following the student uprisings of 1968, the anti nuclear protests of the 1970s and 1980s,[24] and the formation of the Green Party and its entry into the Bundestag in 1983.[25] Not surprisingly, much of the detailed negotiation on the GenTG reflected these driving concerns. On the side of federalism, the Länder joined with Klaus Töpfer's Environment Ministry in pressing for a more decentralized approach to licensing facilities and approving releases.[26] Both researchers and industry, however, favored the more centralized, one-stop approach through the ZKBS, which ultimately prevailed. On the side of participation, activists succeeded in altering the composition of the ZKBS: membership was raised from twelve to fifteen to provide a stronger voice for ecology and environmental protection, and over time the commission took more steps to make available the results of its deliberations. Paralleling Britain's ACRE, which advised the Health and Safety Executive, the ZKBS continued to operate under the jurisdiction of a health rather than an environment ministry. Chancellor Helmut Kohl was allegedly reluctant to

transfer regulatory responsibility for an important industrial sector to his possibly too independent environment minister, Klaus Töpfer.[27] Keeping the ZKBS within the Health Ministry offered a practical solution.

Green activism was also responsible for the insertion of two public hearing requirements into the law, applicable to the construction and operation of genetic engineering facilities and the release of GMOs, respectively.[28] These provisions resembled the hearing requirement in earlier federal legislation on air pollution control, but in applying to institutions conducting basic research on GMOs, the deliberate release provision marked a departure from the prior focus on industrial hazards. It demanded that basic researchers account to the pubic for an aspect of their scientific aims and methods. In addition, paragraph 16 of the law required that releases should produce no unjustified harmful effects on humans, animals, plants, or the environment and property. Together, these changes soon proved consequential.

By the late 1980s scientists in Peter Meyer's research group at the Max-Planck-Institute for Plant Breeding Research (Züchtungsforschung) in Köln had planned and partly conducted a series of experiments designed to test the properties of genetically modified petunia plants. In the first phase, the plants were modified using a corn gene, which activated an enzyme that turned the normally white petunias a deep salmon red color; following the usual custom in such studies, the transgenic plants were also fitted out with a "marker" gene conferring resistance to the antibiotic drug kanamycin.[29] The results were published in the influential science journal *Nature* and attracted considerable media attention (although not, to begin with, in Germany) as a cute example of the funny things scientists do with genetic engineering.[30] In the second phase, researchers wanted to study the behavior of a class of "jumping genes" (transposons), which they expected would selectively turn off the color-producing gene, thereby creating variegated or pale pink flowers. To get meaningful results, Meyer's group planned a study requiring thirty thousand genetically modified plants to be grown in an open field. They were confident, on the basis of both the published literature and their own pilot studies, that no plants would survive from one growing season to another. Accordingly, they were not at all worried about safety.

This would be the second release of GMOs in Germany, but the first conducted in accordance with the procedures envisaged by the GenTG. The earlier release, also originating with Meyer's group, had proceeded without a hitch under the auspices of the ZKBS. The second study required a public hearing in addition to committee approval. That process proved more unruly and discursively undisciplined than the well-intentioned but politically inexperienced scientists had bargained for. Ten hours were consumed in discussing the design and worth of the experiment in order to satisfy the balancing of risks and benefits called for by paragraphs 1 and 16 of the GenTG. To Meyer's and others' deep dismay, environmental activists insisted on addressing

procedural aspects of the hearing process instead of focusing on the study's scientific substance. The intervenors demanded, for instance, that many of the reference papers, which had been submitted in the original English, should be translated into German to facilitate access.[31] Critics, in short, used the occasion to pursue their broader agenda of throwing impediments in the way of what they saw, or at any rate publicly characterized, as unnatural experimentation with nature. All this was a shock to responsible scientists who had gone out of their way to assuage public concern, and they found the activists' behavior both objectionable and contrary to their understanding of the spirit of the law.

The open hearing not only breached scientists' understanding of the appropriate line between substantive and formal arguments, but it also contested their view of the kinds of uncertainties the public had a right to be concerned about. The initial petunia studies had produced some unexpected results. Transgenic plants that were stably colored in the greenhouse refused to stay stable in the outdoor environment, where they turned unexpectedly pale or variegated. Molecular analysis showed that this unpredictability was due not to transposons having excised the inserted genes (the mechanism the scientists wanted to study) but to environmental factors, such as above average heat and light that summer, as well as the age of the seeds from which the crosses had been made.[32] Such serendipitous observations are what science thrives on; they raise the curtain on new vistas of inquiry. In Meyer's view, while scientists owed the public a demonstration of safety, there was no reason, and indeed no basis, for his group to account for unexpected experimental findings. He sharply distinguished the issue of safety, where everything had to work (and apparently did work) according to plan, from the issue of experimental results, where surprise was a legitimate—indeed, for scientists, a most desirable—outcome:

> **PM**: . . . those results were very surprising, but of course, quite interesting for us. Now, all these results, of course, had nothing to do with the safety evaluation of the experiment and when we started the experiment, we said to the public that we would like to perform these experiments because we expect transposons to create variable phenotypes and we wanted to isolate variable phenotypes and we expect that they will be caused by transposons and we need a large number.[33]

The Max-Planck scientists saw no particular contradiction in a study whose results were at once "expected" and "surprising." These were, in Meyer's view, "two different things":

> **PM**: So the results were as expected. The petunias don't spread; they don't survive.
> *SJ*: In terms of safety, the results—or ethics?
> **PM**: That's what I mean. And these are two different things. We always say OK we would like to do an experiment and we can guarantee from our present knowledge,

> as good as we can guarantee, that there will not be any danger, escape, or however you want to call this, [undecipherable] plants. That was part number one, which we thought was what we had to show to the public as best as we could. And the second part was, OK, we want to do an experiment and every experiment, of course, is open in its result, otherwise no funding agency would fund it. But of course we said that is what we expect from the experiment, and it didn't turn out as we expected, and maybe it was a mistake to tell the public, quite frankly, that we were quite happy that we found something which we didn't expect because those are very often the most interesting things. They lead you to new observations . . .[34]

Was Meyer's confidence in the safety studies warranted? In retrospect, we can only say that the premises on which those studies were designed were never carefully probed, although, as Brian Wynne and other science studies scholars have shown, such untested and unstudied assumptions about the social and natural worlds may be thoroughly unfounded.[35] Real-life examples from the U.S. experience with StarLink corn and Prodigene (see chapter 5) still lay in the future. Further, the Max-Planck researchers' focus at the time was on the escape and uncontrolled propagation of the GM plants, and not on questions that transcended the specific experiment and later became controversial, such as the appropriateness of using antibiotic resistance genes as markers. German and international biotechnology critics, at any rate, remained dissatisfied. Although the Max-Planck Institute experiments survived regulatory scrutiny and went forward over initial public objection, they left residual traces of illegitimacy. A decade later, the study was still being cited as an example of the "weird science" of genetic engineering by activist groups such as the Pesticide Action Network North America.[36] Numbers may also tell a part of the story. By 2000 the ZKBS had received a total of 118 applications for deliberate release. Of these, only 3 involved GM petunias.[37]

For the moment, however, German policy on genetic engineering appeared to have reached a workable, if tense, compromise. Public interest groups had gained a new procedural forum in which they could question the goals and premises of genetic engineering. Their questions upset researchers, challenging the scientists' preconceived notions about how far the public should be allowed to go in interrogating science—but in the end, after all the hassles, the research was permitted to go on.

Unraveling: Normalization Breaks Down

Proponents of biotechnology, regulatory harmonization, and technological progress had reason for complacency in the early 1990s. In three leading industrial democracies—the United States, Britain, and Germany—public distrust and angst about a potentially disruptive new technology appeared to

have been confronted and calmed, or in Britain's case avoided through careful management of science's relations with the public. Perceptive observers, however, might have detected clouds forming on the horizon. A tell-tale sign was that, although a consensus of sorts had been achieved, the basis varied from country to country. In the United States science was deemed to have answered, or at least to be capable of answering, all the relevant questions in a regulatory system firmly focused on the risks of particular biotechnological products. In Britain, by contrast, reassurance fell not to science in the abstract, but to a cadre of experienced, managerial scientists like David Bishop and the members of ACRE; it was these experts who diagnosed the public's needs and sought to satisfy them before any hint of trouble. Experts, in short, were entrusted with managing not merely risks but also the publics exposed to them. And in Germany novel procedures were concocted to deal with that country's particular insecurity about the abuse of science, opening a direct and unmediated dialogue between scientists and the public. But attempts to implement these procedures revealed deep conflicts about the very meaning of publicly evaluating the methods and goals of research. These cross-national differences and internal contradictions refused to stay buried and eventually led to renewed controversy.

United States: Science Confounds Science

The institutional structure for evaluating GMO releases in the United States was designed to provide scientifically reliable answers to questions of risk. The lead regulatory agencies responsible for the oversight of biotechnology strengthened their advisory capacities to meet the challenges of this new industrial technology. At the same time, they moved to limit the range of concerns that could properly be voiced during regulatory assessment. When Monsanto began marketing genetically engineered bovine growth hormone, for instance, critics quickly discovered that there was no place in the federal government where they could raise their questions about risks to small farmers or damage to the welfare of treated cattle, let alone economic arguments against generating further surpluses in an already heavily subsidized industry, or ethical concerns about the instrumental use of dairy cattle as machines for high-intensity milk production. These views and values had to find expression in other than official channels—for example, in political cartoons or Internet postings. For purposes of governance, risks were narrowly defined as threats of harm to human health and the environment, and these in turn were felt to be the preserve of scientific analysis.

Almost imperceptibly, the U.S. discourse of regulating agricultural biotechnology began to equate *risk* assessment with *scientific* assessment. Public officials asserted that the only way to manage the threats of biotechnology was through risk assessment based on "sound science." Science, U.S.

administrators and politicians agreed, did not justify any serious worries about the release or consumption of GMOs. For the most part, the public seemed to go along with this assessment. No significant disputes arose as higher and higher percentages of key crops were replaced with transgenic variants. By 1998, 20.5 million hectares were sown with GM crops, up from 11 million in 1997 and 1.7 million in 1996. As a British expert body observed, "These are extremely high adoption rates for a new technology by agricultural standards."[38]

American agricultural biotechnology, then, came to depend on science in two respects: for inventiveness, leading to new products (Wynne calls this "innovation science"), and for regulatory purposes (in my terms, "regulatory science"). Though regulatory science derives constant legitimation from the label "science," sociologically it is a vastly different kind of activity from basic research, at least as that is ideally conceived.[39] An important difference, as Peter Meyer's experiences in Germany also showed, is that regulatory science needs to stay black-boxed, to deny its provisional or indeterminate status, if it is to be credible. Unusually prone to deconstruction in adversarial and political settings, such science depends on institutional closure mechanisms, such as authoritative expert advice, to keep challenges within bounds.[40] Ordinary science by contrast makes advances through uncertainty, provisionality, and surprise. One might expect the fluid and labile character of the latter to threaten the closure-seeking propensity of the former. And indeed, in the United states, the "science" relevant to the safety assessment of transgenic crops refused to stay black-boxed. Two episodes that occurred in 1999 and 2002 were important and illustrative.

In May 1999 John Losey and his colleagues, all entomologists at Cornell University, reported in *Nature* the results of studies they had done on the effects of a transgenic corn species on the monarch butterfly.[41] Known as Bt-corn because it contains genes from the bacterium *Bacillus thuringiensis*, this GM corn variety produces a toxin that is deadly to a common agricultural pest, the European corn borer. Losey's group dusted milkweed leaves with pollen from Bt-corn and fed these to monarch caterpillars, nearly half of which died within days. These results were not just surprising but potentially explosive. The monarch, with its distinctive orange and black coloring and its remarkable migratory habits, is one of America's most distinctive and beloved butterfly species. It is also a so-called nontarget species for Bt-corn, since monarch larvae do not feed on corn but on milkweed. Losey's experiments seemed to show that Bt-corn was dangerous not only to a designated pest, the corn borer, but also to a species that no one had any intention of harming.

The short *Nature* article had consequences beyond anything the authors had imagined. The biotechnology industry went into high gear in attempting to undermine the study's significance, commissioning counter-studies and aggressively marketing "information" to the public. The object

was not to discredit Losey's competence or credibility so much as to make his study seem irrelevant to assessing the risks of Bt-corn. Among the most active players was Monsanto, the world's leading supplier of transgenic crops.[42] Monsanto posted on its "Biotech Knowledge Center" website the argument that "this experiment was conducted in a laboratory, not in the natural habitat of the Monarch butterfly."[43] With these words, the company in effect endorsed and strategically deployed an argument that academic and social critics had long leveled against industrial and governmental claims of safety: that the best test of a product's behavior in the real world is its actual behavior in that world.[44] Lab or field studies, however carefully designed, can do no more than approximate the complexity of actual use in real-world conditions. Indeed, studies done to verify Losey et al.'s conclusions suggested that, although some forms of Bt-corn were toxic to monarch butterflies, these varieties were not the ones in widespread use in U.S. agriculture.

Industry's attempts to refute any logical connection between the monarch study and commercial uses of Bt-corn may have succeeded at the level of professional scientific debate, but they worked substantially less well as a public relations strategy. Environmental and antiglobalization groups found in the potentially threatened monarch an irresistible symbol of the larger problems that they wished to bring to public attention: inadequate environmental testing and monitoring of GM crops, risks to nontarget species, damage to biodiversity, and corporate recklessness. Monarch images and costumes prominently figured in the 1999 riots against globalization in Seattle, Washington. Clearly, activists were unwilling to concede the basic point that "science" had adequately established the safety of products such as Bt-corn. Expert judgment had neither addressed nor answered the foundations of global public concern.

A rather uglier dispute erupted in the spring of 2002, with potentially longer-term consequences for the credibility of science. At issue again was a piece in *Nature*, this time written by Ignacio Chapela, a Mexican scientist, and his student David Quist, both biologists at the University of California, Berkeley.[45] Quist and Chapela reported that they had found evidence of cauliflower mosaic virus genes, commonly used as a promoter in industrially produced transgenic corn, in native ("criolla") strains grown in Mexico's Oaxaca region. Their experiments suggested that genes from bioengineered corn had migrated into native corn even in remote areas, with a likelihood of higher penetration in more accessible regions. The findings were particularly troubling in view of Mexico's having imposed a moratorium on planting transgenic corn in 1998. They were also politically sensitive, given the long history of corn cultivation in Mexico and that nation's strong commitment to protecting the genetic diversity of its native species.

Gene flow, or the transfer of genes from one population to another, has been one of the most hotly debated issues surrounding agricultural biotechnology. Opponents of large-scale commercial applications point to

the possibility of gene flow as a threat to biodiversity, whereas proponents either minimize the probability of such transfers occurring at all or deny that it would be a threat even if it did occur.[46] Unexpected findings such as Chapela's were bound to fuel that ongoing controversy, but the vehemence of the reactions exceeded many expectations. Initial responses included a number of highly critical letters to *Nature* charging that the results were an artifact of poor experimental methods combined with an unfortunate rush to publish. Chapela and Quist had used the technique of inverse polymerase chain reaction (iPCR) to study their samples. This widely used method allows scientists to amplify and analyze small quantities of DNA, but it is also prone to contamination and can produce false positives. As the furor over the paper mounted, critics from industry joined the chorus, alleging that the authors had allowed their politics to override their science: they were behaving, in short, as "activists," not "scientists." Chapela, his detractors noted, had a history of political activism. He had opposed a five-year deal between the Swiss pharmaceutical and agrochemical company Novartis (later Syngenta) and Berkeley's Department of Plant and Microbial Biology, in which the company had agreed to pay the department twenty-five million dollars for research in return for benefits such as first rights to patents on potential discoveries. How could a person who had fought this deal conduct a neutral inquiry into the environmental consequences of agricultural biotechnology? In return, supporters of Chapela and Quist accused the attackers of illegitimate political motives and hidden connections to industry.[47]

Matters came to a head on April 4, 2002, when Philip Campbell, the respected editor of *Nature*, took the unprecedented step of withdrawing the journal's support for the contested article. It was not a retraction but something distinctly odder. Along with two letters critical of Chapela's results, Campbell published a note in the journal's online version stating that "the evidence available is not sufficient to justify the publication of the original paper." New data submitted by the authors had failed to establish "beyond reasonable doubt" that transgenes had been integrated into native corn genomes. Since the authors still stood by their original findings, however, Campbell felt it best "simply to make these circumstances clear, to publish the criticisms, the authors' response and new data, and to allow our readers to judge the science for themselves."[48]

In effect, Campbell's action opened the door to an unprecedented form of postpublication peer review. It was as if the first round of review, favorable to the authors, had only served as the "field test" of initial editorial scrutiny and approval. Now that the results were in full-blown public circulation, they had also, according to *Nature*'s editor, laid themselves open to a kind of scaling up, to extended peer review. But the consequence arguably was to subject an article on GM crops to a greater degree of scrutiny than the crops themselves had undergone in their passage from lab to field to commercial cultivation.

We will revisit the university-industry links that figured so prominently in the Mexican corn controversy in chapter 9. For present purposes, the more important point is the curious way in which this controversy at once undermined and sustained the status of *science* in the biotechnology debate. At one level, most observers agreed that science had been shown to be political, indeed that it was unavoidably so. At another level, appeals to science continued, especially in the comments of critics who portrayed Chapela and Quist as having fallen short of well-recognized canons of objectivity and good scientific practice. What lent irony to these charges was that the entire episode had disclosed just how fluid and unsystematic were the methods for investigating the environmental behavior of transgenic crops. Even *Nature*'s peer review practices with regard to such studies were shown to be subject to contingent pressures and flexible interpretations.[49] Philip Campbell's admirably honest invitation to readers to make their own assessments of "the science" only heightened the irony by abdicating editorial omniscience while retaining power to exercise it, and by openly admitting the subjectivity of scientific judgment under conditions of uncertainty.

Britain: Weakening Expertise

If the authority of science weakened in the United States under the stresses of supporting agricultural biotechnology, then it was the culturally sanctioned concept of expertise that came under comparable pressure in Britain. As we will see in the next chapter, it was not genetic modification but bovine spongiform encephalopathy (BSE), or "mad cow disease," that posed the most visible threat to expert authority in the 1990s. Yet well before the BSE crisis grabbed the center of political attention, British scientists, policymakers, and members of the concerned public had begun to question the meaning of expertise in relation to something so complex and hard to pin down as the risks of deliberate release. Some signs of the waning of expert authority were highly visible, while others remained more circumscribed, but it was clear by the end of that politically troubled decade that public policies for biotechnology would have to find new ways of engaging with, and reassuring, an increasingly skittish consuming public.

The fate of David Bishop, the cautious Oxford virologist who once made "such a meal" of his public relations, provides one instructive angle of vision. In the spring of 1994, field tests conducted by the Institute of Virology came under intense scrutiny because the terms of the experiments had changed dramatically. Interested now in concrete products, the institute had moved to test a viral pesticide with an inserted scorpion gene; this manipulation allowed the virus to produce a toxin that would quickly and efficiently kill plant pest caterpillars—more so, it was hoped, than conventional chemical pesticides. The GM virus, the *Autographa californica NPV* (*AcNPV*), was to

be tested on the cabbage looper, prompting joking references to cabbage patches, but also serious scientific and public concerns. In particular, Bishop's scientific colleagues in Oxford and elsewhere voiced a number of objections that were picked up and disseminated by the national media.

Openly on the table was whether Bishop, widely viewed as a strong and opinionated research leader, had adequately considered the risks of release, but additional questions revolved around who actually was responsible for making binding judgments on such issues. There were several technical questions that opponents of the release felt had been inadequately addressed. How could earlier trials conducted with enfeebled viral species be used to justify the release of an organism that was fully biologically active, and "unnatural" on top of it?[50] Scientists also questioned the likelihood of restricting the *AcNPV* to a particular target (the cabbage looper) when tests suggested that it could affect up to one hundred species of butterflies and moths. The fact that this was a nonnative virus, and that the release site was within close proximity of Wytham Woods, a "treasure trove" of lepidopteran biodiversity, only made matters worse in the critics' view. In an unusual move, some scientists even considered legal action to block the release, although it eventually went forward with approval from ACRE and the relevant government ministries.[51]

Other themes emerged as the trials were conducted, all consistent with Britain's initial framing of biotechnology as a process deserving special concern. The first was that of unintended consequences. Early reports from the pesticide trial suggested that some stocks of the engineered virus had become contaminated with the nonengineered wild type, making the experimental results uninterpretable. Although not specifically pertinent to the earlier debate on risk, the episode underscored the unpredictability of working with GMOs and contributed to doubts about the commercial viability of such products.[52] The second theme was accountability, as reports circulated that Bishop's team had failed to disclose potentially damaging data about the range of species affected by the engineered virus.[53] The third, and for us most interesting, theme was the dissatisfaction some scientists expressed with the culture of regulatory expertise that had permitted the *AcNPV* trials to proceed. Foreshadowing the criticism unleashed by the BSE crisis, Steve Jones, professor of genetics at University College London, took government scientists to task for their "'nanny knows best' attitude." He also voiced an empiricist's impatience with the sloppiness of the approval process: "They say the virus is not going to escape. If you look at the proposal that's clearly not true. They can by no means guarantee that this sodding virus is going to stay there."[54]

Less than a year later, in March 1995, David Bishop, the man at the center of the controversy, was abruptly dismissed from his post by the Natural Environment Research Council, under whose aegis he had functioned for eleven years as IVEM director. Publicly, NERC denied that the *AcNPV* trials had anything to do with the firing and even asserted that the trials would

continue.[55] Bishop's dismissal was attributed to "structural redundancy" as a result of changes in NERC's research mission. Privately, people cited complaints from Bishop's coworkers about the nondisclosure and even distortion of data in the 1994 viral release application.[56] Perhaps fittingly, the man who decided Bishop's fate was John Krebs, NERC's chief executive, who would later become the first head Britain's Food Standards Agency, formed to restore public confidence in the wake of the BSE scandal.

The scorpion gene episode, capped by Bishop's sudden departure, was the most public controversy in the early development of British agricultural biotechnology. The anxieties it disclosed, however, were not limited to that single event, and geneticists were not the only ones worried about proceeding too far too fast with an untried technological process. Similar concerns surfaced in the work of the British Government Panel on Sustainable Development, headed by veteran diplomat and environmentalist Sir Crispin Tickell, a highly regarded member of Britain's "great and good." The panel selected biotechnology for its second report, issued in January 1996, months before the explosive turn taken by the BSE case.[57] Tickell himself wrote up the issue, nervous at first about going in over his depth, but also convinced (in part through representations from respected environmental groups such as the Green Alliance) that the government had paid insufficient attention to problems such as monitoring deliberate releases. The panel's objective, he said, was to set off a firecracker, and it succeeded in catching the government off guard: "It touched a raw nerve."[58] Within months the government responded, more extensively than the panel had expected, and, while continuing to assert its commitment to biotechnology, conceded that most of the problems identified in the panel report were well founded.[59] In a foretaste of things to come, the government agreed that its risk appraisal, emergency measures, and liability provisions might not adequately address all of the panel's concerns about agricultural biotechnology.

Political upheavals over the next few months and years gave new urgency to the precautionary trends illustrated by these events. The BSE crisis of early 1996 (of which more in chapter 5) helped open the door to the Labour Party's triumphant return to power under Tony Blair in 1997, with a mission to reform government and make it more transparent and accountable. Health and environmental regulation emerged as primary sites of institutional innovation, offering comparative analysts unparalleled opportunities to ask what changed and what remained the same in Britain's institutional ways of decision making. Following a review in 1999, the government decided it needed a broader range of inputs into its strategic framework for both green (agricultural) and red (pharmaceutical) biotechnology. Consequently, a new twenty-member Agriculture and Environment Biotechnology Commission (AEBC) was appointed in June 2000 to offer strategic advice and to work more closely with two other newly created committees, the Food Standards Agency and the Human Genetics Commission.

The new committee structures broadened earlier understandings of expertise by drawing a wider spectrum of opinion into the advisory process. AEBC members included academics and practitioners, scientists and ethicists, farmers and industrialists. This widening of the opinion network inevitably shifted the terms of debate on GM plants, particularly by placing the topic of uncertainty squarely on the table. At the same time, it did not resolve the tensions within Britain's empiricist culture between some who saw the absence of evidence as evidence of the absence of risk, and others who took the same absence as sheer ignorance, pointing to as yet unknown and unimagined threats. An exchange between Robin Grove-White, professor of environment and society at Lancaster University and chairman of UK Greenpeace, and the chairman of ACRE, who gave evidence for the AEBC report *Crops on Trial*,[60] illustrates the clash of perspectives and the emergence of a new line of conflict:

> RGW: Do you think people are *reasonable* to have concerns about possible "unknown unknowns" where GM plants are concerned?
> Advisory scientist: *Which* unknowns?
> RGW: That's precisely the point. They aren't possible to specify in advance. Possibly they could be surprises arising from unforeseen synergistic effects, or from unanticipated *social* interventions. All people have to go on is analogous historical experience with *other* technologies . . . .
> Advisory scientist: I'm afraid it's impossible for me to respond unless you can give a clearer indication of the unknowns you're speaking about.[61]

As the exchange makes clear, the question about the safety of organisms in Britain's GM advisory circles had subtly shifted from "How safe is safe enough?" to "When, with what evidence, and on whose assertion, is it reasonable to raise a safety concern?" These questions were anything but academic. AEBC took office in an atmosphere of crisis about the future of GM crops in Britain. Protests by environmental groups, ranging from destroying field trial sites to lawsuits, had brought field trials by firms such as AgrEvo (later Aventis) to a virtual halt. *Crops on Trial*, one of AEBC's first work products, recommended a systematic program for proceeding with farm-scale trials in Britain. In its response, the Department of Environment, Food, and Rural Affairs again stated that there would be no authorization of commercial planting of GM crops until the likely conclusion of farm scale trials and full regulatory evaluation of the results in 2003.

Germany: Containing the Process

And what of Germany, where Green mobilization had put programmatic issues of transparency, participation, and institutional reform on the biotechnology policy agenda in the 1980s, several years ahead of comparable moves

in Britain? Just as science and expertise proved insufficient to hold the line against skepticism in the United States and Britain, respectively, so Germany's process-based approach also gave way under strain. Indeed, one major procedural innovation of the 1990 GenTG, the public hearing on deliberate release, was repealed just three years later, leaving the ZKBS with greater freedom to establish risk categories and assess new releases without significant public oversight or intervention. How can we explain this retreat?

An official stocktaking of experiences in the first two years under the GenTG points to some of the reasons. The occasion was a hearing of the parliamentary Committee for Research, Technology and Technology Assessment held in February 1992. A list of questions circulated before the meeting asked specifically for reactions to the public consultation requirements of the new law. Several respondents addressed the question, and opinion was sharply divided. The submission from Hoechst, one of the first German companies to be targeted by antibiotechnology forces,[62] noted that no hearings pursuant to the GenTG had been held in its home state of Hessen but nonetheless criticized even hearings held under prior law as ill-suited for drawing the public into a constructive dialogue with science. Participants, Hoechst argued, had not posed pointed, factual questions but instead had raised general objections to genetic engineering. The company quoted from a leaflet of a women's group, Bürgerinnen beobachten Petunien (Citizenesses Observe Petunias), declaring that it would use every means at its disposal to damage the reputation of genetic engineering and prejudice the investment climate against biotechnology.[63] From within the government, the Robert Koch Institute (RKI) took a similar line, pointing out that the great majority of the 1,600 submissions to the petunia hearing had raised either general reservations about biotechnology or else purely formal complaints about the application materials, such as their incompleteness and the use of English. The hearing, moreover, had entailed costs on the order of DM 100,000 as compared with DM 1,000–1,500 for normal ZKBS evaluations. Under these circumstances, the RKI concluded, the benefits of citizen participation did not justify the expense.[64] On these utilitarian grounds, RKI experts in effect refuted the proposition that citizens *had* to be involved as watchdogs over the relations between science and government. It was the ultimate victory for the calculating administrative state.

It seems in retrospect that, for all these observers, it was not the petunia release but the public hearing that was the more unusual experiment. Hearings made sense, in their view, only if they served as a public sphere in the Habermasian sense. Participants were expected to engage in informed debate, conforming to industry's and government's preconceived notions of rational inquiry. A hearing was meant to corral public opinion within appropriate limits, much as physical containment devices corralled GMOs. Strategic use of the hearing by participants to advance a broader political agenda

subverted this construction of the purpose of public consultation. Citizens had been given a chance to behave responsibly, as reasoning actors, and they had failed the test.

Gerd Winter, writing for the Center for European Law Politics (Zentrum für Europäische Rechtspolitik, ZERP) at the University of Bremen, offered a very different analysis. Citizens, he argued, had good reason to question the goals and benefits of biotechnological production. Hearing administrators had therefore erred in excluding queries on this score. An analysis of benefits was required, Winter suggested, not only to enable citizens to form a holistic picture of the risks they would be exposed to, but also pursuant to the precautionary principle. After all, how could state authorities assess the acceptability of a project's risks *without* considering its goals? If the purpose was of questionable social value, then the associated risks could not be socially tolerable. Winter also urged more openness in the operations of the ZKBS, citing the U.S. Government in the Sunshine Act as a model. The commission, he asserted, was not a secret service but represented a mechanism for activating social expertise.[65] Consistent with this role, information had to flow out of, as well as into, the ZKBS, and its members—especially those representing segments of civil society—had to be free to relay information to their constituencies outside the commission. In other words, Winter, too, stressed the informational and opinion-making functions of the public hearing and of ZKBS, but in his view the adequacy of these processes was to be judged from the standpoint of the "at risk" or "to be informed" citizen—not from that of the state's interest in scientific freedom, industrial productivity, or governmental efficiency.

The 1993 amendments to the GenTG paid more attention to complaints from science and industry, and to the government's own experts, than to arguments like Winter's or from environmentalists in favor of openness and participation. In particular, the research community's charge that excessive bureaucracy was stifling German science and destroying its competitiveness proved effective,[66] and the 1993 legislation streamlined many aspects of the approval process for both marketing and release. German authorities also cited the European directive, 90/220/EEC, as grounds for simplifying their own approvals process and for eliminating the public hearing on releases. Few noted that this victory for scientific experimentation entailed a defeat for the social experiment of involving the public more fully in the management and control of biotechnology.

Protests over field trials of GM crops continued in Germany as in Britain, although in Germany, too, commercial planting remained banned into the next decade. In 1999, for example, Rainder Steenblock, the Green Party environment minister of the northern Land of Schleswig Holstein objected to federal authorization of a trial of genetically modified oilseed rape.[67]

His objection raised renewed questions about federalism and the capacity of a central authority, the Robert Koch Institute, to resolve local environmental concerns regarding GM crops. As late as spring 2003, Greenpeace activists sabotaged the approved site for a planned trial of Syngenta's GM wheat, near the northern city of Hamburg, by sowing it with organic wheat seeds.[68] Such actions prompted German researchers, in turn, to keep secret the locations of fields sown with GM corn—a course that activists denounced as contrary to European law.[69]

Conclusion

In the late 1980s and early 1990s, the United States, Britain, and Germany all put in place new procedures and principles for managing the risks of GMO releases into the environment. National strategies and policy discourses differed, reflecting the historical origins and forms of debate in each country, and the consequent framings of biotechnology as product, process, or program. More specifically, different institutional and discursive resources were mobilized to ward off criticism and reassure the public: in the United States "science" was said to have confirmed the safety of most releases; in Britain it was not so much science as expert judgment that formed the basis for assertions of safety; and in Germany, to begin with, bureaucratic procedures and public consultation were the instruments of choice for allaying the fears of a nervous citizenry.

Curiously, each mode of stabilization carried within it the seeds of its own vulnerability. U.S. science proved less monolithic and less quiescent than the most ardent biotechnology proponents would have wished. Ecologists' concerns about huge, unprecedented, and largely unmonitored environmental experimentation never fully faded, and findings like those of Losey and Chapela indicated, at the very least, how many aspects of environmental risk had never been fully tested. In Britain the regulatory and political upheavals of the early 1990s undermined the social role of the expert, forcing the creation of new advisory institutions that were both more diverse and more transparent. In these forums, traditional standards for evaluating evidence were challenged, revealing new fault lines between those demanding empirical evidence of risk to justify more stringent regulation and those urging greater precaution in the presence of unknown unknowns. The German case is in many ways most interesting, because here an experimental democratic settlement was undone in favor of a return to a more technocratic approach. The deeper point, however, is that the very idea of a universally acceptable process, creating an open deliberative space for science and technology, proved untenable in Germany, just as the facticity of science and the reliability of expertise had done in the United States and Britain.

The unraveling of the early regulatory settlements led, in turn, to new controversies and new attempts to forge consensus on biotechnology policy. The issue of deliberate release remained heavily contested in both Britain and Germany into the early years of the twenty-first century, though both countries had delayed commercialization in favor of continued, supervised scientific experimentation. In the next chapter, we turn to another contested site, the debates over the safety of foods derived through GM techniques.

[. . .]

CHAPTER 4: UNSETTLED SETTLEMENTS

1. The concept of "regulatory science" and the dynamics of its production in the United States were elaborated in Jasanoff, *The Fifth Branch.*

2. "A Timeline of Biotechnology," compiled by the Biotechnology Industry Organization, http://www.biospace.com/articles/timeline.cfm; see also http://www.bio.org/er/timeline.asp (both visited July 2002).

3. Beck, *Risk Society.* Originally published in Germany as *Risikogesellschaft: auf dem Weg in eine andere Moderne* (Frankfurt: Suhrkamp, 1986), the book created an immediate stir and sold more than 100,000 copies.

4. Hacking, *The Taming of Chance.*

5. Barry A. Palevitz and Ricki Lewis, "Perspective: Fears or Facts? A Viewpoint on GM Crops," *The Scientist* 13, 20 (October 11, 1999): p. 10.

6. *Foundation on Economic Trends v. Heckler*, 756 F.2d 143 (D.C. Cir. 1985); see chapter 2.

7. For a detailed account of the events surrounding the release, see Sheldon Krimsky and Alonzo Plough, *Environmental Hazards: Communicating Risks as a Social Process*, chapter 3, "The Release of Genetically Engineered Organisms into the Environment: The Case of Ice Minus" (Dover, MA: Auburn House Publishing Company, 1988), pp. 75–110.

8. Palevitz and Lewis, "Perspective: Fears or Facts?"

9. Brian Tokar, "Resisting the Engineering of Life," in Tokar, ed., *Redesigning Life? The Worldwide Challenge to Genetic Engineering* (London: Zed Books, 2001). For a picture of the AGS scientist, Julie Lindemann, spraying the field site, see Mark Crawford, "California Field Test Goes Forward," *Science* 236, 4801 (1987): 511.

10. Paul Slovic, "Beyond Numbers: A Broader Perspective on Risk Perception and Risk Communication," in Deborah G. Mayo and Rachelle D. Hollander, eds., *Acceptable Evidence: Science and Values in Risk Management* (New York: Oxford University Press, 1991), pp. 48–65; Slovic et al., "Characterizing Perceived Risks," in Robert W. Kates, Christoph Hohenemser and Jeanne X. Kasperson, eds., *Perilous Progress: Managing the Hazards of Technology* (Boulder, CO: Westview, 1985), pp. 91–125; Slovic et al., "Facts and Fears: Understanding Perceived Risk," in R. Schwing and W. A. Albers, Jr., eds., *Societal Risk Assessment: How Safe is Safe Enough?* (New York: Plenum, 1980), pp. 181–214.

11. Mark Crawford, "RAC Recommends Easing Some Recombinant DNA Guidelines," *Science* 235, 4790 (1987): 740–741.

12. Henry I. Miller, "The Big Fed Freeze."

13. See, for example, Gina Kolata, "How Safe Are Engineered Organisms?" *Science* 229, 4708 (1985): 34–35. See also Gottweis, *Governing Molecules*, pp. 235–236.

14. Tokar, *Redesigning Life?*

15. Microbial pesticide research continued, but the focus shifted from uses in ordinary agriculture to agents, often fungus-based, that were used to combat dangerous

plants, such as opium in Latin America. These new agents were also potential instruments of biological warfare. Protest over ice-minus may have played a role in driving the demand for research on microbial pesticides from civilian to military end-users.

16. Jonathon Porritt, "Down-to-Earth Agenda; Suggestions to Mrs. Thatcher," *The Times (London)*, September 27, 1988. The full text of the speech can be found at the home page of the Margaret Thatcher Foundation, http://www.margaretthatcher.org/default.htm (visited April 2004).

17. Interview, David Bishop, Institute of Virology and Environmental Microbiology, Oxford, July 5, 1990.

18. Les Levidow, "The Oxford Baculovirus Controversy—Safely Testing Safety?" *Bioscience* 8, 45 (1995): 545–551.

19. Interview, U.K. Advisory Committee on Releases to the Environment, London, July 16, 1990.

20. Levidow, "The Oxford Baculovirus Controversy" (quoting Alan Lees, a campaigner for Friends of the Earth, who characterized the enfeebled baculovirus as "a Trojan horse for the genetic engineering industry").

21. On this point, see particularly Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge: MIT Press, 1990); Pinch, "'Testing—One, Two, Three . . . Testing!'"

22. Steven Dickman, "New Law Needs Changes Made," *Nature* 343 (1990): 298.

23. *Bericht über die zurückliegende Amtsperiode der Zentralen Kommission fur die Biologische Sicherheit, (29.01.81 bis 30.06.88)*, Bonn, 1989.

24. Dorothy Nelkin and Michael Pollak, *The Atom Besieged: Extraparliamentary Dissent in France and Germany* (Cambridge: MIT Press, 1981).

25. Eva Kolinsky, ed., *The Greens in West Germany: Organisation and Policy Making* (Oxford: Berg, 1989); see also Gottweis, *Governing Molecules*, pp. 237–245.

26. Steven Dickman, "Germany Edges towards Law," *Nature* 339, 6223 (1989): 327.

27. Klaus Töpfer served as federal minister for the environment, nature conservation, and nuclear safety from May 1987 to November 1994.

28. *Gentechnikgesetz*, sections 18(1) and 18(2) (1990).

29. Marker genes make it possible to isolate transgenic plants on the basis of their acquired resistance. The widespread use of antibiotic resistance genes in such studies was not at this time a matter of great public concern.

30. Peter Meyer et al., "A New Petunia Flower Colour Generated by transformation of a Mutant with a Maize Gene," *Nature* 330 (1987): 667–668. Highly colored accounts of the study appeared in several English-language papers. See, for instance, Boyce Rensberger, "Making a Pink Petunia Turn Red," *Washington Post*, December 21, 1987, p. A3.

31. Peter Meyer, "Regulations for the Release of Transgenic Plants according to the German Gene Act and Their Consequences for Basic Research," *AgBiotech News and Information* 3, 6 (1991): 999–1001.

32. Peter Meyer et al., "Endogenous and Environmental Factors Influence 35S Promoter Methylation of a Maize A1 Gene Construct in Transgenic Petunia and Its Color Phenotype,' *Molecular and General Genetics* 231 (1991): 345–352.

33. Interview with Peter Meyer, Max-Planck Institute for Plant Breeding Research, Köln, July 1993.

34. Ibid.

35. Irwin and Wynne, eds., *Misunderstanding Science?*

36. "A field test of genetically engineered petunias that were designed to produce one color wound up having wildly fluctuating results in the field." Richard Caplan and Ellen Hickey, "Weird Science: The Brave New World of Genetic Engineering," October 21, 2000, http://www.mindfully.org/GE/GE-Weird-Science.htm (visited April 2004).

37. "Elfter Bericht nach Inkrafttreten des Gentechnikgesetzes (GenTG) fur den Zeitraum 1.1.2000 bis 31.12.2000," *Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz* 9 (2001): 929–941.

38. Nuffield Council on Bioethics, *Genetically Modified Crops: The Ethical and Social Issues* (London: Nuffield Council on Bioethics, 1999), p. 31.

39. Jasanoff, *The Fifth Branch*, pp. 76–83.

40. Jasanoff, "Science, Politics, and the Renegotiation of Expertise at EPA; *Risk Management and Political Culture.*

41. John E. Losey, Linda S. Rayor, and Maureen E. Carter, "Transgenic Pollen Harms Monarch Larvae," *Nature* 399 (1999): 214.

42. According to the company's own promotional web site, "Monsanto is the world leader in biotechnology crops. Seeds with Monsanto traits accounted for more than 90 percent of the acres planted worldwide with herbicide-tolerant or insect-resistant traits in 2001." http://www.monsanto.com/monsanto/layout/about_us/ataglance.asp (visited August 2002).

43. Monsanto, "Bt Corn and the Monarch Butterfly," Biotech Knowledge Center, http://www.biotechknowledge.monsanto.com/biotech/knowcenter.nsf/f055f4dc645999ad86256ac4000e6b68/0231086dd38f9a3d86256af6005433ae?OpenDocument (visited August 2002). An interesting rhetorical feature of the entries under this heading is the repeated reference to the Losey group's study as a "Cornell report," omitting any mention of its publication in *Nature*.

44. See, for instance, Donald MacKenzie's extended demonstration that the accuracy of the U.S. antiballistic missile system was "invented." Mackenzie, *Inventing Accuracy*.

45. David Quist and Ignacio H. Chapela, "Transgenic DNA Introgressed into Traditional Maize Landraces in Oaxaca, Mexico," *Nature* 414 (2001): 541–543.

46. See, for example, Marc Kaufman, "The Biotech Corn Debate Grows Hot in Mexico," *Washington Post*, March 25, 2002, p. A9.

47. Bizarre twists in the story included the charge that biotechnology companies had invented fake people to attack Chapela and Quist on the Internet. Industry representatives vehemently denied this accusation. George Monbiot, "The Fake Persuaders: Corporations are inventing people to rubbish their opponents on the internet," *The Guardian*, May 14, 2002, p. 15.

48. See Philip Campbell, "Editorial Note," *Nature* 416 (2002): 601.

49. Scientific journal editors often adjust the stringency of their peer review practices to take account of factors such as the novelty and possible political impact of research reports. See Jasanoff, *Fifth Branch*, pp. 66–68. The peculiarity in this case was the editor's delegation of interpretive discretion to the journal's readership.

50. Levidow, "The Oxford Baculovirus Controversy," p. 545.

51. On these points see the series of articles published from May to November 1994 by Susan Watts, science correspondent for the *Independent*, in particular, Watts,

"Genetics Row Fueled by Scorpion's Venom," *Independent*, May 17, 1994, p. 3; "Legal Fight Planned to Halt Scorpion Toxin Test," *Independent*, May 18, 1994, p. 3; "Warning: This Thing Isn't Natural," *Independent*, May 26, 1994, p. 20; "Safety Scare on Eve of Mutant Virus Test," *Independent*, June 26, 1994, p. See also Editorial, "Controversy in the Cabbage Patch," *Independent*, May 17, 1994, p. 15.

52. Susan Watts, "Genetic Riddle of 'Scorpion' Pesticide Virus, *Independent*, September 4, 1994, p. 2; Oliver Tickell, "Scorpion Gene Virus Experiment Abandoned," Pesticides *News*, no. 25 (September 1994), p. 21.

53. Watts, "Safety Scare."

54. Watts, "Legal Fight."

55. Steve Connor, "Gene Scientist 'Sacked without Warning,'" *Independent*, March 18, 1994, p. 5; Christian Tyler, "Private View: Professor with Killer Gene Blues," *Financial Times*, April 8, 1995, p. 18.

56. "Scorpion Has Sting in Tale," *The Splice of Life*, Bulletin of the Genetics Forum, 1, 8/9 (May 1995).

57. British Government Panel on Sustainable Development, *Second Report*, January 1996.

58. Interview, Sir Crispin Tickell, Warden, Green College, Oxford, July 9, 1996.

59. Government Response to the Second Annual Report of the Government's Panel on Sustainable Development, Department of the Environment, London, March 1996.

60. Agriculture and Environment Biotechnology Commission, *Crops on Trial* (September 2001), www.aebc.gov.uk/aebc/pdf/crops.pdf (visited July 2003).

61. Robin Grove-White, "New Wine, Old Bottles? Personal Reflections on the New Biotechnology Commissions," *Political Quarterly* 72, 4 (October 2001): 466–472.

62. Jasanoff, "Product, Process, or Programme."

63. Position paper of Hoechst AG, submitted to Hearing on Experiences with the Law for Regulating Questions of Gene Technology, January 31, 1992, pp. 16–17.

64. Position paper of Robert Koch Institute, Federal Health Office, submitted to Hearing on Experiences with the Law for Regulating Questions of Gene Technology, February 7, 1992, pp. 9–11.

65. "Die Tätigkeit in der ZKBS ist kein Geheimdienst, sondern Aktivierung gesellschaftlicher Sachkunde." Gerd Winter, position paper of ZERP, University of Bremen, submitted to Hearing on Experiences with the Law for Regulating Questions of Gene Technology, January 28, 1992, p. 15.

66. The Munich-based Max-von-Pettenkofer Institute, for instance, endorsed the views expressed on this score by the influential Max-Planck Institute for Biochemistry in Martinsried and appended to its own position paper a *Science* article rehearsing the obstacles that the new law posed to free inquiry and exchange; see Patricia Kahn, "Germany's Gene Law Begins to Bite," *Science* 255 (1992): 524–526.

67. Quirin Schiermeier, "German Transgenic Crop Trials Face Attack," *Nature* 394 (1998): 819.

68. Planet Ark, "German GM Wheat Trials Approved but Site Sabotaged," Hamburg, April 11, 2003, http://www.planetark.org/dailynewsstory.cfm/newsid/20444/ newsDate/ 11-Apr-2003/story.htm (visited July 2003).

69. Ned Stafford, "GM Crop Sites Stay Secret," *The Scientist*, 28 May 2004, http://www. biomedcentral.com/news/20040528/02 (visited June 2004).