Bio*in*security and Vulnerability

Edited by Nancy N. Chen and Lesley A. Sharp



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Biosecurity in the Age of Genetic Engineering

Glenn Davis Stone

In Ulrich Beck's *Risk Society* (1986), a book on how post-industrial society was changing with the advent of qualitatively new and spatially unbounded risks, genetic engineering was barely mentioned. Yet, in 1986, the era of recombinant DNA was already fourteen years old; bacteria had been engineered to produce medicines and other compounds; and experiments with transgenic plants were moving ahead quickly. Genetically modified (GM) crops would be available to farmers in the United States by 1994, and by 1998, Western Europe would be embroiled in a clamorous debate over how to even think about the new technology.

Stung by charges of risky and Frankensteinish meddling with life, biotechnologists took to insisting that genetic engineering was qualitatively no different from what humans had done for millennia. Crop domestication itself was nothing but "prehistoric genetic engineering" (Fedoroff 2003). All GM crops were simply "not dangerous" (Fedoroff 2011); indeed, they were "risk-free" (Benaning 2012; Biolife News Service 2012).

I agree that the use of recombinant DNA per se is not intrinsically risky or dangerous; in fact, I do not regard risk as intrinsic to any technology, but rather as a function of our ability to identify, understand, and manage possible unwanted outcomes. My concern here is not about the risks of manipulating DNA, but about changes in the institutions and practices of

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generating and characterizing information about risks. Beck (1996) may have overlooked it, but genetic engineering may best exemplify his characterization of global risk society as "a phase of development of modern society in which the social, political, ecological and individual risks created by the momentum of innovation increasingly elude the control and protective institutions of industrial society" (see also Beck 1999:72).

The "protective institution" of primary concern here is academic science, specifically, the research universities in the United States (the country that has dominated genetic engineering). It was academic research that pioneered genetic engineering and has provided most of the findings behind commercialized GMOs. I argue that, as a scientific tool, genetic engineering can answer previously unanswerable questions, but only as it produces novel questions requiring answers for the sake of biosecurity; it answers questions while increasing our effective ignorance. Insert a gene and you may answer questions about how that gene works, but you will also generate a rash of questions about how the genetic changes affect the organism and how the organism may affect ecosystems. "Bioinsecurity" here is not just that altered organisms may pose threats, but that the system for studying threats has been compromised. In fact, a biotechnology establishment (comprising new types of alliances between industry and academy) is active in blocking potentially uncomfortable research on the impacts of genetic engineering.

This chapter has four sections. In the first, I consider concepts for dealing with the politics of knowledge and ignorance, reconfiguring recent writing on what has been termed "agnotology" (the creation of ignorance). I argue that this term has been used for practices that are not truly agnotological, which genetic engineering is—in two distinct senses. In the second section, I look at genetic engineering and the biological ignorance it creates, which is the first sense of true agnotology. In the third section, I examine how the development and deployment of GM crops have been inextricably linked to changes in institutions for developing and deploying information. Two such developments—the rise of academic capitalism and of new intellectual property regimes—have hampered the very processes of the scientific research needed to meet these challenges. These practices are the second sense of true agnotology. In the final section, I return to issues raised by Beck.

TRUE AGNOTOLOGY

Corporate informational damage control has emerged as an issue in social science in the twenty-first century, including Proctor and others'

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(Proctor and Schiebinger 2008) development of the concept of agnotology. To Proctor, "agnotology" refers to the construction of ignorance in general—the broadening of a concept inspired by his subject, the tobacco industry, which saw "doubt as [its] product" (Michaels 2008). The doubt was specifically about the harmful effects to smokers' health that were being documented mostly by academic scientists, and the industry-generated ignorance consisted of public confusion about and distrust of the findings. Such deliberately created ignorance is termed "construct agnotology," in contrast to native ignorance or lost knowledge (Proctor 2008). Rayner (2012) parses the range of agnogenic (ignorance-creating) tactics for handling "uncomfortable knowledge," including "denial, dismissal, diversion and displacement." Benson and Kirsch (2010) identify the phases of corporate treatment of uncomfortable knowledge as denial, symbolic gestures, and appropriation of discourse (for other schemas of ignorance, see Smithson 2008).

But the genetic engineering case forces us to rethink the range of agnotological projects. The uncomfortable knowledge that concerned the tobacco industry was in published work by non-industry scientists; the industry was not blocking this research, but simply putting into play the meaning, significance, and certainty of the findings. Industry disinformation programs were truly agnotological only in a limited sense; they did inhibit public awareness, understanding, and acceptance of uncomfortable knowledge and may have indirectly foreclosed some forms of knowledge production. However, their primary action was to confuse and obscure the meaning and importance of extant scientific knowledge. A more accurate term would be "ainigmology," from the root *ainigma* (as in "enigma"); in Greek, it refers to riddles or to language that obscures the true meaning of a story.

In contrast, genetic engineering presents us with two types of true agnotology (or, actually, agnogenesis). The first is a direct function of the technology itself: genetic engineering alters and recombines DNA from multiple organisms and then causes the modified DNA to insert into various loci in target organisms, which may then be released into nature. Each step raises new questions about the current and future operation of the organism and how it will affect other organisms. Each successful transformation event (see below) creates an organism that has never existed before. Of course, all organisms (save clones) are genetically unique, but the tools that can create, alter, and move specific pieces of DNA among organisms open the possibility of unprecedented variations in life forms. There are, then, many questions that for the sake of our biological security should be answered. This is why I say that genetic engineering creates effective

ignorance, a category that does not figure in Proctor's typology of native ignorance, lost knowledge, or instrumentally constructed ignorance. As sketched below, scientists address only a fraction of the effective ignorance they create with genetic engineering.

But—and this brings us to the second type of true agnotology in genetic engineering—an array of forces in the world of genetic engineering actively *prevents* research to address effective ignorance, because of the "risk" of generating uncomfortable knowledge. This is accomplished mainly through the levers of intellectual property law and through control of funding, which is linked to the rise of academic capitalism.

GENETIC ENGINEERING: INFORMATION REPLACING STUFF

It now seems ironic that we were proclaimed to have entered the post-industrial "Information Age" in the 1960s (Matchlup 1962), because there has been an exponential increase in the amount of information generated and trafficked since then. With the emergence of genetic engineering, agriculture entered an era in which the main value of technological inputs was informational, because genetic engineering is all about information—generating it, owning it, and suppressing it.

Knowledge production obviously played a role in previous revolutions in agricultural technology. The fertilizer revolution of the mid-nineteenth century—the first major phase of industrialization in agriculture—was stimulated by findings in the new field of agricultural chemistry (Foster and Magdoff 2000). But the real value of fertilizer was in the stuff itself, which had to be mined and transported in large quantities or industrially fixed. With GM crops, the real value is in the highly research-intensive genetic information leading to changes in the DNA of existing seeds. As Monsanto's chair, Robert Shapiro, put it, "information replaces stuff" (qtd. in Charles 2001:270).

As a scientific tool, genetic engineering has been invaluable in knowledge production, especially in fields such as functional genomics. Yet, as noted, it is a highly agnotological technology, capable of generating unprecedented variation in life forms and thus unprecedented effective ignorance. This in itself is not necessarily dangerous; the danger of any technology can be assessed only in the context in which it is made and used. A nuclear bomb is, in an obvious sense, much more dangerous than a handgun, but handguns have killed far more people. Cell phone technology per se may not be hazardous, yet texting drivers kill many people each year. Rather than ask whether GM crops are "more dangerous" than

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conventional crops, the question should be how the practices required for safe use differ between GM and conventional crops. The short answer is *research*: as a major intervention into the blueprints of organismal function, agricultural genetic engineering increases our effective ignorance by several orders of magnitude, and it has voracious research and informational requirements to be safe. As a research tool, it can reduce certain important types of ignorance, but as an applied technology, it creates vital new unanswered questions. It is this inevitable increase in effective ignorance that makes the protective function of science more important than ever, and impediments to that function are a source of bioinsecurity.

A brief explanation of plant genetic engineering will be helpful here. DNA is a long molecule containing genes, which are sequences of nucleotides that are translated into proteins according to a language that is universal across the biological kingdoms and viruses. In most crop genetic engineering, DNA segments (including "structural genes" that actually encode proteins, as well as segments that regulate gene expression) are isolated, recombined, and inserted into target plants.

Insertion is done by different mechanisms. One method uses the soil bacterium Agrobacterium tumefaciens, which naturally inserts its genes into plants via plasmids (extrachromosomal rings of DNA); biologists create a new DNA payload on the plasmid and then turn the Agrobacterium loose on target organisms. Another method is to put the payload onto a projectile, which is then shot into target organisms with a modified gun. It is important that biologists do not have control over, or even a detailed understanding of, the process by which either Agrobacterium or the gene gun inserts DNA into the genomes of target organisms. In the vast majority of the cells in target organisms, none of the payload DNA is integrated into the genome at all. The cases in which the payload is integrated into a cell's DNA are called "transformation events," and each event is unique: the payload DNA may be intact or fragmented, may be inserted any number of times, may be in any location, and may be inside native genes or between them. Either transformation process itself may have extraneous effects on the target organism's DNA. To genetically modify an organism in this way requires the brute force approach of exposing many cells to the vector and then seeing which cells have been transformed and in which the payload is working. (This is precisely why some engineers resent the term "genetic engineering.")

Most writers deal with the effective ignorance generated by GM plants in terms of taxonomies of risk (Rissler and Mellon 1996; Street 2007; Weaver and Morris 2005).² Concerns over biological risks are often integral to

ethical concerns (Gregorowius, Lindemann-Matthies, and Huppenbauer 2012). However, my concern is not with ethics or biological risks per se, but with bioinsecurity resulting from science not being willing or able to answer questions about risk. Therefore, let us consider types of effective ignorance according to the inclination and ability of research scientists to address them.

Ignorance Internal to the GMO

One category of effective ignorance pertains to how the introduction of exogenous DNA affects the functioning of the target organism. Some questions are so basic to the experiment that they are built into standard protocols. In the attempt to insert genes into an organism, only a small percentage of the target's cells take up the DNA, so the first line of effective ignorance is whether this has even happened. With plant experiments, the gene of interest is usually paired with a gene that acts as a "selectable marker," which is used to isolate the cells in target organisms that have been transformed. Most commonly, this is a gene for antibiotic resistance, allowing the scientist to isolate the transformed cells by applying a normally lethal dose of antibiotics.

But after this is a very long list of questions that vary in their importance for publication, use in a commercial product, or requirement for approval. How many copies of the gene have been introduced into the target organism? How is the gene being expressed? Does the introduced gene confer the desired trait? How stable is the transformation? What other effects on the organism does the introduced gene have? Particularly important here are pleiotropic effects, that is, multiple phenotypic traits from a single gene. Pleiotropic effects are common and were a real concern in the first application for commercial release of a GM crop (Martineau 2001). These effects may be exceedingly difficult to identify, however, especially if they become manifest only after some time or under specific conditions. Pleiotropic traits are often discovered years after the crop's release. For instance, one of the first two GM foods still sold in the United States, the virus-resistant squash, is now known to have pleiotropic traits affecting pollinator behavior (Prendeville and Pilson 2009). It has also been found that the glyphosate-tolerant (GT) gene in GM canola has pleiotropic effects on flower production (Pierre et al. 2003).3

There may also be changes in the target organism that are seen not in the phenotype but only in analysis of its DNA. Both common methods of transforming plants lead to poorly understood alterations of DNA. The

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gene gun commonly leads to insertion of "multiple, rearranged, and/or truncated transgene fragments" (Pawlowski and Somers 1998:12106). A good example of extraneous, unexplained, and initially undetected DNA from *Agrobacterium*-mediated transformation occurred in the most commonly planted GM crop in the world—glyphosate-tolerant soybean. Five years after GT ("Roundup-Ready") soybeans were approved for sale, it was found that the original characterization of the transgenic plant's DNA had missed a rearrangement or large deletion of DNA, as well as an unknown segment of inserted exotic DNA (Windels et al. 2001). There is no evidence that this "mystery DNA" (Pollack 2001) has harmful effects, but the point is that its safety had not been investigated before approval *because it had not been detected*. Four years later, researchers found an additional fragment of the gene resulting in four different RNA variants (Rang, Linke, and Jansen 2005), which might code for unknown proteins (Magaña-Gómez and Calderón de la Barca 2008:10).

Academic reward structures today militate against extensive research on risks. For scientific publication, only a minute subset of these questions need be answered; to market GM seed, the questions to be answered are specified in the "coordinated framework" involving three federal agencies, a jury-rigged regulatory system largely shaped by biotechnology firms (Eichenwald, Kolata, and Peterson 2001; Jasanoff 2005; Schurman and Munro 2010). As the new forms of effective ignorance become less essential to the interests of those carrying out the genetic engineering, they are less likely to be researched. The biologist always has to find out which cells have integrated the exotic DNA and always has specific questions about how the new genes are expressing. But identifying pleiotropic effects may or may not be essential for publication, patenting, or commercialization, and some such effects may be discovered only years later, if at all. Complete characterization of the genome of a GM plant is normally considered prohibitively expensive and unnecessary; thus, today's farmers annually plant more than eighty million acres of GT soybean containing mystery DNA.

Ignorance External to the GMO

As complicated as it is to ascertain exactly how a GMO operates, it is much more complex to determine how it will operate in an ecosystem. The behaviors and impacts of a GM plant will vary in space, and changed interactions between species may take years to manifest (Saxena, Pushalkar, and Stotzky 2010).

The ecological questions raised by releasing GM crops are vast. Research

on ecological impacts are outside the normal set of interests (as well as the training) of microbiologists conducting genetic engineering. Ecologists differ from biotechnologists in their training and also in the political economy of their work: they are not normally rewarded for developing technologies that "work," they do not patent or commercialize their findings, and they benefit little from biotechnology industry funding. The issue of what ecological questions need to be answered is hotly contested, frequently with microbiologists squaring off against ecologists.

One set of questions concerns the impacts on cultivated crops, with the long-running issue of introgression into landrace maize in Mexico showcasing how little we know. After Mexico banned the planting of GM maize out of concern for gene flow into landraces, the ecologists Quist and Chapela (2001) reported transgenes in landrace seeds and further asserted that the transgenes had unstably integrated into the corn genome. Furor followed (more over the second claim than over the more important first one), featuring a barrage of attacks from academics, industry personnel, and public relations firms, featuring invented characters, petitions, and threats (Monbiot 2002; Worthy et al. 2005). A subsequent study failed to find transgenes but assumed that they had been present before and speculated on why they might have disappeared (Ortiz-García et al. 2005). A later study again found transgenes (Piñeyro-Nelson et al. 2009). If we are unsure about the presence of transgenes in Mexican maize, we are totally in the dark about the potential impacts of transgenes on agricultural systems. Interactions between transgene introgression and farmer behavior are bound to be complex (Cleveland and Soleri 2005), and the answer to most of the key questions is "We don't know" (Soleri, Cleveland, and Aragón Cuevas 2006).

Another set of questions concerns the potential GM crop impacts on ecosystems. Outcrossing by GM crops can affect pollinator behavior (Prendeville and Pilson 2009) and viruses in wild plants (Laughlin et al. 2009; Prendeville 2010), although no one knows how these changes might affect population dynamics. One of the two widely planted GM technologies is Bt-based insect resistance, the effects of which on ecosystems are especially poorly known. One study of Bt proteins on nontarget beneficial insects found "positive, negative and no effects" (Groot and Dicke 2002:387). A study in the midwestern United States found that 23 percent of streams contained Bt proteins from GM maize (Tank et al. 2010), and it has been shown that feeding on Bt maize byproducts increases the mortality of some stream insects (Rosi-Marshall et al. 2007), but "it is unknown if

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there are ecological consequences for stream-dwelling organisms that are exposed to the dissolved [transgenes]" (Tank et al. 2010:17648).

Better known are some unfortunate impacts of GM crops on weeds. The widespread planting of transgenic herbicide-resistant crops leads to herbicide-resistant weeds through two different routes. One is transgenic plants pollinating weeds: for instance, one study in North Dakota found that 80 percent of wild mustard plants along roadsides contained herbicide-resistant transgenes from GM canola (Schafer et al. 2011). Resistant weeds also arise under the strong selective pressure from heavy herbicide use, allowing the emergence of tenacious and costly weeds (e.g., Binimelis, Pengue, and Monterroso 2009; Duke and Powles 2009). The forthcoming generation of GM crops is resistant to broadleaf herbicides 2,4-D and dicamba. This will result in a major surge in these herbicides in the environment, the effects of which are a key subject of effective ignorance. Activists' labeling of these as "Agent Orange crops" is an overstatement, but even after sixty years of use of 2,4-D, we are still unsure of its impacts on human health (Freese 2012), and we know even less about the ecosystemic impacts of greatly increased spraying.

There has been more research on GM crops' human health impacts than on their environmental impacts, not only because of the sociomoral logic (Sharp, Chapter 3) but also because of the political risk to government and the economic risk to industry. Prior to the release of the first GM food crop in the United States—Calgene's delayed-rotting Flavr Savr tomato—Calgene scientists went to considerable pains to evaluate the crop's potential health impacts. However Belinda Martineau, one of the leaders of Calgene's "regulatory science" on the tomato (and chronicler of the process; see Martineau 2001), was later disturbed that similar research was not done on subsequent GM food crops. There is now evidence of GM crops having possible public health impacts that were not even conceived of in the early 1990s. Studies have documented herbicides (or their metabolites) associated with GM crops in human blood (Aris and Leblanc 2011; Hori et al. 2003; Motojyuku et al. 2008). No one knows what, if any, effect their presence has on human health.

The point is not that we are endangered, but that we are ignorant. We are increasingly relying on a category of technology that, for all its promise, exponentially raises our effective ignorance. This places unprecedented demands on science to answer proliferating questions. But GM technology has been joined at the hip with institutional, economic, cultural, and legal changes that fundamentally impact scientists' behavior in addressing these questions.

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AGNOTOLOGY AND INSTITUTIONAL CHANGES IN SCIENCE

Genetic engineering is an agnotological technology, bringing a suite of potential risks to public health and the environment, the identification and mitigation of which are highly research-intensive endeavors. Historically, we have expected science to study such risks, which is one of the reasons that so much pure science is publicly supported. Robert Merton famously identified the hallmarks of "pure science" to be universalism, communism, disinterestedness, and organized skepticism, and scientists in the academy are still expected (and believed) to follow a strict set of ethics consistent with Merton's values (Kenney 1987:128). Merton's account of the behavior of scientists may sound quaint to those accustomed to the analytic gaze of science and technology studies (Kleinman 2003; Knorr-Cetina 1981, 1999; Latour and Woolgar 1979) or may even sound like "mythmaking" (Vallas and Kleinman 2007:9), but Merton did not attribute scientists' behavior to their values and ethical compass. He saw the public service of scientists as entirely instrumental: institutionalized arrangements evolved to motivate scientists to contribute to the common wealth of knowledge. To Merton, science was based on something akin to private property, created by a perverse form of privatization based on disclosure: "Only when scientists have published their work and made it generally accessible...does it become legitimately established as more or less securely theirs" (Merton 1988:620). The core reward structure of academic science was thus aligned to make it function as a "protective institution of industrial society."

The pure science establishment famously responded in its protective capacity early in the era of genetic engineering. In 1973, a committee of distinguished biologists asked the field to voluntarily avoid certain types of particularly risky experiments (Berg et al. 1974). In 1975, more than a hundred biologists and others met at Asilomar to address issues of risk (Berg and Singer 1995; McHughen and Smyth 2008). The concern was with recombinant bacteria and viruses, and the early recommendations were basically for laboratory safeguards, not for "protective" research. After GM plants were developed, academic scientists held a 1988 risk assessment conference at the University of California, Davis. These early calls for caution and self-policing are preserved as part of the origin narrative of biotechnology, reinforcing the notion that the biotechnology establishment itself is an effective protective institution (Torrance 2012:329). This conviction continues to be promoted today as if there has been no change in the reward structures underlying the protective functions of science.

But there has been change, and it directly affects how bioscience

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self-polices and approaches research on risk. New technologies may have profound effects on how science institutions operate and relate to one another. For instance, Kloppenburg (2004) shows that the real change wrought by hybrid corn was not in the farmer's field, but in how scientific institutions behaved. From the moment transgenic organisms were created, changes were set in motion in divisions of labor, in flows of funding and information, in intellectual property, in allegiances, and more generally in "lifeworlds" (Schurman and Munro 2010). A new set of relationships between the academy and industry grew along with the genetic modification of plants. In one of many examples, Monsanto helped to support early work at Washington University on Agrobacterium and virus-resistant technology (getting coownership of the resulting technologies; Charles 2001) and then made a \$23 million deal to sponsor the university's medical school research, with 70 percent going toward "applied research" (Kenney 1986). The National Research Council (NRC) found that both parties benefited from such "new research partnerships" and noted, too, that society benefited from the accelerated technological innovation (NRC Board on Agriculture 1984:60).

What the NRC failed to ask was which kinds of innovative research would be fostered by the new industry-academy partnerships, which kinds would be discouraged, and which information would be suppressed. Integral to the growth of the biotech industry has been a suite of factors that have given the industry unusual influence over research, which directly affects which kinds of knowledge are and are not created. Two such factors are the rise of academic capitalism and the intellectual property regime.

Genetic Engineering and the Rise of Academic Capitalism

Several observers see the late twentieth-century growth of the "academic-industrial complex," or academic capitalism (Culliton 1982; Kenney 1986; Slaughter and Leslie 1997; Slaughter and Rhoades 2004), as a major revolution in the United States. Genetic engineering has played a central role in this revolution. In contrast to China's model of state-funded biotechnology (Chen, chapter 5), US academic capitalism was stimulated by major reductions in government research funding (partly due to the expense of the Vietnam War). This happened in the early 1970s, just as recombinant DNA was being developed (Etzkowitz 1989; Washburn 2005:57–59). Meanwhile, the quickening pace of technological development and the downsizing of firms to core competencies opened up an "innovation gap" even before the rise of genetic engineering (Etzkowitz and Leydesdorff 1997). This left the corporate sector increasingly hungry for innovative research from the academy.

Thus, economic conditions were already favoring a new integration of industry and the academy by 1980, when a sea change occurred in legislation and in case law: the *Chakrabarty* case (see below) opened the door to the privatization and commodification of genes, and the Bayh-Dole law allowed the private sale of results of federally funded academic research. The fledgling field of genetic engineering promptly became a major driver of the new entrepreneurial university. Various arrangements by which universities provided corporations with research in exchange for funding were quickly hammered out (Busch et al. 1991; Culliton 1982; Kenney 1986), leading to a new merging of the interests of basic scientists and corporations. Thus, universities, from which we might reasonably expect the "disinterested" investigation of the health impacts of GMOs, increasingly equated public benefit with commercialization (Glenna et al. 2007a; Kenney 1986:68).

The new industry-academic relationships are important to biosecurity because of their impact on how academic researchers select research subjects, choose genes, characterize findings, share information, and form attitudes and values about risks and benefits (Busch 2000; Busch et al. 1991; Kenney 1987). It was clear early on that industry funding had a chilling effect on communication among scholars (Blumenthal et al. 1986). It seems clear that biotechnology has become a leading example of economics driving research agendas (Oehmke 2005:7), with applied projects strongly promoted over basic research (Glenna et al. 2007b; Kenney 1986). Criteria for academic tenure and promotion may now include "numbers of patents, numbers of companies, the commercialization and the impact of that on the economy" (Vallas and Kleinman 2007:10). This renders hazards research, which could obstruct the commercialization of a technology, a hazardous career strategy.

Intellectual Property

Closely linked developments in patent law and genetic engineering have combined to have profound effects on agnotology. The utility patent gives the holder the absolute power to block others from making, selling, or even using its invention for a fixed period (currently, twenty years from filing in the United States). Prior to the advent of genetic engineering, crops and genes were not eligible for utility patents; they were covered instead by weaker protections that allowed use by others in research (Kloppenburg 2004). Utility patents, in contrast, were intended for actual "inventions" and have no exemption for research.⁴

The US Supreme Court's 1980 Chakrabarty decision was one of the

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most agnotological judgments ever handed down. It allowed utility patents on GMOs, opening the door to gene patenting a few years later and crop patenting after that (Torrance 2010:176).⁵ Remarkably, the Court failed to even consider that utility patents on GMOs (and later, on genes) would bestow the power to block research. It opined that patent law would not "deter the scientific mind from probing into the unknown any more than Canute could command the tides." The decision led to a tsunami of DNA patents, mostly in corporate hands, each of which can stop scientific research dead in its tracks and keep the scientific mind from probing at all. Although patent holders often turn a blind eye to academic infringers over research that may benefit them (Weschler 2004), they have repeatedly blocked research on their plants and genes, sometimes in the middle of a study, to avoid the production of uncomfortable knowledge. The entomologist Ken Ostlie was forced to stop his research on Bt corn because one company decided the study was "not in its best interest" (Pollack 2009); the ecologist Allison Snow was forced to stop her research on the ecological impacts of Bt sunflowers after she found that Bt-wild hybrids had a selective advantage (Dalton 2002; Snow et al. 2003). As with Chapela's case around the same time, Snow's research attracted stunning vitriol. The biotechnologist Neal Stewart (2003:353) suggested that the reports on her findings had contributed to Africans' starving to death.

More commonly, patent holders prevent research from even starting. In 2009, twenty-six leading scientists submitted an anonymous statement to the government saying that they were being blocked by patent-holding companies from doing necessary research (Anonymous 2009; Pollack 2009). Monsanto, Syngenta, and Pioneer all cited intellectual property concerns in defending their policies.

The plants that Ostlie and Snow could not study may not pose any danger. But what these cases show is that in this era of unprecedented effective ignorance and reliance on science for biosecurity, the intellectual property regime integral to biotechnology allows unprecedented obstacles to scientific research.

UNKNOWN KNOWNS

I have argued that institutional and legal developments integral to genetic engineering are truly agnotological in that they militate against research on the dangers of GM crops. However, it is impossible to characterize the research that has been prevented. The documented cases of constructed agnotology, such as the studies aborted by patent holders, only hint at the ecologists who never got permission to begin a study of

gene flow, or those who opted not to even try to study GM crops' ecological impacts after seeing the careers of young ecologists consumed in vitriol (Waltz 2009), or the students who chose careers in microbiology over ecology because biotechnology was better funded by corporations. We do not know what we might know today were it not for these factors that distort research; this remains, with apologies to Donald Rumsfeld, a matter of "unknown knowns."

What we do know is that the trickle of published research on the impacts of GM crops increasingly provides grounds for concern about the depth and extent of our effective ignorance. The ignorance I am describing is not simply on the part of consumers (as Chen, chapter 5, describes for China), but on the part of science. I have sketched only a few examples, and environmental risks will only expand as more and different GM crops are released (Andow and Zwahlen 2006).

Not surprisingly, the extent and significance of our ignorance are hotly contested, and as is true of a wide range of situations—as disparate as US biotechnology and Ghanaian land disputes (Rouse, chapter 7)—the struggle to assert control over the narrative is crucial to how risk is handled. With GM crops, the struggle is dominated by two polarized narratives. We are playing "genetic roulette," according to one major anti-GMO book (Smith 2007). Meanwhile, to many in the ostensibly protective institution of academic biology, GM crops are not only safe but also overstudied. In this view, the focus on the potential risks of GM crops is hindering the technology and risking sure starvation (Fedoroff 2011; McGloughlin 1999). This "biotech Neo-Malthusianism" (Stone 2005) confidently stresses figures on how much more food we will need by some landmark date in the future usually, 2050 (e.g., Fedoroff 2011). Malthusian warnings play a unique and intriguing role in the struggle over risk narratives; although they are sometimes supported by explicit (if dubious) analyses, as Watts (chapter 8) describes, they are routinely allowed with great confidence and little support (as Caton, chapter 6, describes for Yemen). This is interesting from the perspective of agnotology because population figures for decades out are unknown and unknowable; demographers have no basis whatsoever for predicting the reproductive behavior of people not yet born (Cohen 1995). These Malthusian claims might be thought of as ainigmology, but readers of Greek philosophy may recognize an even more apt term: claiming to know what they did not actually know is precisely the charge of Socrates against the Sophists in Plato's Dialogues, from whence we get the negative connotation of the term "sophistry."

BIOSECURITY IN THE AGE OF GENETIC ENGINEERING

BACK TO BECK

This chapter begins with Ulrich Beck's neglect of genetic engineering in the "risk society." But my consideration of certain biological, institutional, and legal aspects of crop biotechnology suggests that this technological regime is particularly instructive as to the nature of bioinsecurity today. To Beck, science is a knowledge-generating project that may, through its successes, generate new risks. He writes, "New knowledge can transform normality into threat overnight. Nuclear energy and the hole in the ozone layer are prominent examples. Therefore, the progress of science refutes its original security assurances. It is the successes of science that sow the seeds of doubt concerning its declarations of risk" (Beck 2007:35).

But, in this account, the same science that splits the atom and creates chlorofluorocarbons also reveals the impacts of radiation and of lowered filtering of ultraviolet light; it is at once dangerous and protective. But we create a more insidious form of risk when the creative endeavors rush ahead ever faster and the protective functions are stymied. Agnotology itself is what endangers us. This is happening on various scientific fronts. We cannot find out how dangerous fracking is, because of the natural gas industry's control over academic geology (McDonnell 2012); we do not know whether neonicotinoid insecticides are causing bee colonies to collapse, because of the pesticide industry's control over academic entomology (Schacker 2008; Schiffman 2012). But plant genetic engineering creates vast effective ignorance with each transformation event and each resulting plant that may be eaten or released into nature. This is not so much a matter of "transform[ing] normality into threat overnight" as it is creating a new normality, demanding a new set of security assurances that require further scientific research to address the effective ignorance and to answer the new questions. But the questions vary in crucial ways in how they articulate with scientists' reward structures. Some are such central measures of "success" as to be an essential part of the laboratory protocol; some are too time-consuming or expensive to be researched; some are practically unanswerable; and some are potentially so uncomfortable that the industry-academy nexus is heavily invested in blocking research on them—the ultimate agnotology.

Bioinsecurity in this case results not from the technology per se, but from the relations among institutions that the technology has occasioned. Given the current state of academic capitalism, intellectual property laws, and polarization in GMO debates, it is difficult to imagine that this will change. "The kind of science that would be needed to understand the

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products of genetic engineering," Magnus (2008:257–258) writes, "is not the kind of science that now exists."

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Notes

- 1. I am referring to the creation and use of recombinant DNA through the techniques of microbiology, glossed here as genetic engineering or genetic modification. "Genetically modified organism," or GMO, refers to an organism containing recombinant DNA.
- 2. My main concern here is with physical risks, that is, possible impacts on public health and the environment from genetic engineering. However, it is vital to remember the presence of political-economic risks. Genetic engineering has been joined at the hip to the privatization of genetic resources, which has led to increasing corporate control over the food supply (Kloppenburg 2004). I would be remiss not to note the creeping corporate control of the factors of agricultural production as a source of bioinsecurity.
- 3. Glyphosate is the active ingredient in Roundup herbicide. Glyphosate tolerance is the most common recombinant trait in commercial use.
- 4. The only exempted uses are "acts of amusement, idle curiosity, or strictly philosophical inquiry" (Weschler 2004:1541).
- 5. The argument for DNA being a patent-eligible "invention" and not a "product of nature" is that it is transformed when used in genetic modification; specifically, it is "purified and isolated" outside its natural environment. This problematic argument (Conley 2009) was challenged in the *Myriad* case, in which the Supreme Court raised the bar for patent eligibility, albeit ambiguously (*Association for Molecular Pathology et al. v. Myriad Genetics, Inc., et al.*, 569 US 12-398 [2013]).
 - 6. Diamond v. Chakrabarty, 47 US 303, 305 (1980).

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