City University of New York (CUNY)

CUNY Academic Works

Publications and Research

CUNY School of Law

2004

Consuming (F)ears of Corn: Public Health and Biopharming

Rebecca Bratspies

CUNY School of Law

[How does access to this work benefit you? Let us know!](#)

More information about this work at: https://academicworks.cuny.edu/cl_pubs/222

Discover additional works at: <https://academicworks.cuny.edu>

This work is made publicly available by the City University of New York (CUNY).

Contact: AcademicWorks@cuny.edu

Consuming (F)ears of Corn: Public Health and Biopharming

Rebecca M. Bratspies[†]

*I'm convinced that physical containment is overrated and, while reassuring to the psyche, is hardly the line of defense one would like to put the greatest reliance upon.*¹

*So what you have to keep asking yourself is: Suppose the worst happens, what are the consequences?*²

I. INTRODUCTION

We have entered the biotech century. Advances in biotechnology³ are already transforming medicine, agriculture, and industry in ways undreamt of thirty years

[†] Associate Professor, CUNY School of Law. I would like to thank B. Allen Schulz for his feedback and support, Greg Jaffe of Center for Science in the Public Interest for generously providing me with information, and Dean Phil Peters from the University of Missouri College of Law-Columbia for suggesting the project to me. I would also like to thank Jane Edwards, Kathy Prince, and their research staff for invaluable research assistance.

¹ Letter from Dr. Paul Berg, Chair of the National Institutes of Health Advisory Committee Concerning Recombinant DNA Technology, to Dewitt Stetten; *see also* MICHAEL ROGERS, BIOHAZARD 151 (1977) (reflecting on the relaxed adherence to safety protocols for biotechnology research).

² Michael Specter, *The Pharmageddon Riddle*, NEW YORKER, Apr. 10, 2000, at 58, 67 (quoting Robert B. Shapiro, former Chief Executive Officer and Chair of Monsanto, Inc.).

³ Article 2 of the Convention on Biological Diversity defines biotechnology as “any technological application that uses biological systems, living organisms or derivatives thereof to make or modify products or processes for specific use.” CONVENTION ON BIOLOGICAL DIVERSITY, art. 2, USE OF TERMS, *at* <http://www.biodiv.org/convention/articles.asp?lg=0&a=cbd-02> (last updated Dec. 6, 2003). The United States defines biotechnology as “the use of modern scientific techniques, including genetic engineering, to improve or modify plants, animals, and microorganisms.” U.S. DEPARTMENT OF STATE, FREQUENTLY ASKED QUESTIONS ABOUT BIOTECHNOLOGY, *at* http://usinfo.state.gov/ei/economic_issues/biotechnology/biotech_faq.html (last visited June 26, 2004). The U.S. State Department and the U.S. Department of Agriculture (“USDA”) also provide useful glossaries of biotechnology. *See* U.S. DEPARTMENT OF STATE, GLOSSARY OF BIOTECHNOLOGY TERMS, *at* <http://usinfo.state.gov/journals/ites/0903/ijee/glossary.htm> (last visited June 26, 2004); ECONOMIC RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE, HARMONY BETWEEN AGRICULTURE AND THE ENVIRONMENT: CURRENT ISSUES, *at* <http://www.ers.usda.gov/Emphases/Harmony/issues/genengcrops/terms.htm> (last updated July 9, 2002). The USDA site also refers users to the more complete the United Nations’ Food and Agriculture Organization Glossary of Biotechnology for Food and Agriculture which defines biopharming as “[t]he use of genetically transformed crop plants and livestock animals to produce valuable compounds, especially

ago, and the pace of scientific advances can only be expected to accelerate. Just as the industrial revolution completely transformed the era of craft and guild production, the world that biotechnology produces may be all but unrecognizable from today's vantage point.⁴

One of the most controversial and exciting prospects of biotechnology is biopharming—a process in which plants are genetically modified so that they endogenously produce specialty pharmaceutical or industrial proteins.⁵ Many such crops are currently being planted in small test plots throughout the country.⁶ Once they are fully developed and approved, these biopharm crops will be grown in the same agricultural fields that are currently devoted to producing traditional agricultural crops.⁷

Biopharm companies envision a lucrative future in which agricultural fields, converted into biofactories, grow the raw materials for industrial or pharmaceutical production. Among the dazzling possibilities are plants that produce specialty industrial compounds like biodegradable plastics⁸ and polyesters;⁹ or drugs to treat a variety of human diseases, such as cancer, HIV, and Alzheimer's.¹⁰ The allure of these crops is clear—an environmentally sustainable¹¹ and inexpensive replacement for costly drugs and petrochemicals.¹²

pharmaceuticals." A. ZAID ET AL., GLOSSARY OF BIOTECHNOLOGY FOR FOOD AND AGRICULTURE—A REVISED AND AUGMENTED EDITION OF THE GLOSSARY OF BIOTECHNOLOGY AND GENETIC ENGINEERING (2001), available at <http://www.fao.org/DOCREP/004/Y2775E/y2775e07.htm#bm07.1>. The biotechnologies discussed in this article are all rooted in insights developed through molecular biology and genetics.

⁴ See Chris R. Somerville & Daroi Bonetta, *Plants as Factories for Technical Materials*, 125 PLANT PHYSIOLOGY 168 (2001).

⁵ Biopharming involves inserting novel genes into crop plants, like corn, in order to make the plants manufacture proteins that may be used as drugs, vaccines, enzymes, antibodies, hormones, or industrial chemicals. Essentially biopharming converts plants into a living factory for chemical or pharmaceutical production. Although biopharming uses food crops as its production vehicle, biopharm crops are not food and are not intended for human consumption. See STATE PIRGS, STATE PIRGS' CAMPAIGN ON GENETICALLY ENGINEERED FOODS, at <http://pirg.org/ge/GE.asp?id2=10570&id3=ge&> (last visited June 26, 2004).

⁶ See ANIMAL AND PLANT HEALTH INSPECTION SERVICE, USDA, BIOTECHNOLOGY REGULATORY SERVICES, CURRENT STATUS OF RELEASE PERMITS, at <http://www.aphis.usda.gov/brs/status/relday.html> (last visited July 23, 2004) (listing test plots all around the country.)

⁷ There are generally three types of biobased products in various stages of planning or production: commodity chemicals (e.g., ethanol or oil-based inks), specialty chemicals (e.g., pharmaceuticals and plastics), and materials (e.g., wood and paper). Biobased commodity and materials production will largely be outside the scope of this article because the various proposals being floated do not typically involve plants bioengineered to express novel, non-food compounds.

⁸ Henry Daniell, *Environmentally Friendly Approaches to Genetic Engineering*, 35 IN VITRO CELLULAR DEV. BIOLOGY-PLANT 361, 361 (1999) (citing other sources).

⁹ Somerville & Bonetta, *supra* note 4, at 169; Christine Nawrath et al., *Targeting the Polyhydroxy-butyrate Biosynthetic Pathways to the Plastids of Arabidopsis Thaliana Results in High Levels of Polymer Accumulation*, 91 PROC. NAT'L ACAD. SCI. U.S. 12760 (1994).

¹⁰ COMMITTEE ON BIOBASED INDUSTRIAL PRODUCTS, NATIONAL RESEARCH COUNCIL, BIOBASED INDUSTRIAL PRODUCTS: RESEARCH AND COMMERCIALIZATION PRIORITIES (2000).

¹¹ Farming already raises a host of environmental issues, many of which are addressed by existing environmental laws, albeit poorly. For example, factories must comply with environmental statutes, including the Clean Water Act ("CWA"). However, environmental harms, such as agricultural run-off, are not regulated under the CWA. Biopharm crops will require tremendous inputs of fertilizer and pesticides, and runoff will likely introduce toxins and pollutants into the environment.

¹² Biopharming may reduce U.S. dependence on foreign oil. See, e.g., Melvin Calvin, *New Sources for Fuels and Materials*, 219 SCIENCE 24 (1983) (speculating that gene transfer could be used to develop new fuels). For current developments in biofuels and bioenergy, see OFFICE OF ENERGY

At the same time, there are some jarring points of tension, if not outright contradiction, between widespread planting of biopharm crops and the ongoing expectation of a safe and secure food supply.¹³ Biopharming frequently uses corn and other food crops as production vehicles, but these crops are emphatically not food and are not intended for human consumption.¹⁴ Biopharm crops, therefore, pose “a wholly different order” of environmental and human health risks.¹⁵ Despite the unique risks, biopharm crops have been tested in fields across the country under the same laissez-faire standards used for first-generation genetically modified (“GM”) crops—with minimal and poorly enforced safety precautions based on physical containment.¹⁶ In the last decade, biotech companies and research universities have violated even those minimal safety precautions more than a hundred times.¹⁷ Because many of these open-air field tests of experimental biopharm crops take place in the Corn Belt, these violations put the food supply at a high risk for contamination.¹⁸

Contamination of food crops with non-food, biopharm compounds is a serious threat to human safety and could result in rapid dissemination of non-food pharmaceutical or industrial compounds through the world food supply. There is no room for trial and error. Once contamination occurs, it will be next to impossible to reverse this process and “uncontaminate” the food supply.¹⁹ Unfortunately,

EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY, BIOFUELS FOR SUSTAINABLE TRANSPORTATION, at <http://www.ott.doe.gov/biofuels/> (last updated May 14, 2004).

¹³ See Memorandum for the President’s Council on Food Safety, Aug. 25, 1998, available at <http://www.foodsafety.gov/~dms/fs-wh13.html> (describing national expectations of food safety). This article focuses on human health questions raised by the likelihood of commingling biopharm crops with conventional crops destined for use as food or feed. The ethical considerations, additional human health implications and environmental effects of biopharming, while significant, are beyond the scope of this Article.

¹⁴ COMMITTEE ON ENVIRONMENTAL IMPACTS ASSOCIATED WITH COMMERCIALIZATION OF TRANSGENIC PLANTS, NATIONAL RESEARCH COUNCIL, ENVIRONMENTAL EFFECTS OF TRANSGENIC PLANTS: THE SCOPE AND ADEQUACY OF REGULATION 246 (2002) [hereinafter ENVIRONMENTAL EFFECTS].

¹⁵ *Id.*

¹⁶ For a description of some of these requirements, see Rebecca Bratspies, *The Illusion of Care: Regulation, Uncertainty and Genetically Modified Food Crops*, 10 N.Y.U. ENVTL. L.J. 297, 310-14 (2002); see also GREGORY N. MANDEL, GAPS, INEXPERIENCE, INCONSISTENCIES, AND OVERLAPS: CRISIS IN THE REGULATION OF GENETICALLY MODIFIED PLANTS AND ANIMALS, available at <http://www.ssrn.com/abstract=418221> (June 19, 2003).

¹⁷ APHIS, USDA, BIOTECHNOLOGY REGULATORY SERVICES, COMPLIANCE AND ENFORCEMENT, at <http://www.aphis.usda.gov/brs/compliance.html> (last visited June 26, 2004). Although the Animal and Plant Health Inspection Service (“APHIS”) characterizes this as a low number of violations, and therefore a success story, others are far less sanguine about the conclusions to be drawn from this number. See, e.g., THE PEW INITIATIVE ON FOOD AND BIOTECHNOLOGY, ACADEMIA/INDUSTRY VIOLATED USDA RULES, at <http://pewagbiotech.org/buzz/display.php3?StoryID=114> (last visited June 26, 2004).

¹⁸ Indeed, in 2002, the Office of Science and Technology Policy acknowledged the significance of this risk. For proposed federal actions to update field test requirements for biotechnology derived plants and to establish early food safety assessments for new proteins produced by such plants, see 67 Fed. Reg. 50,578, 50,587 (Aug. 2, 2002) (“As the number and diversity of field tests increase, the likelihood that cross-pollination due to pollen drift from field tests to commercial fields and commingling of seeds produced under field tests with commercial seeds or grain may also increase. This could result in intermittent, low-levels of biotechnology-derived genes, and gene products occurring in commerce that have not gone through all applicable regulatory reviews.”).

¹⁹ In the context of first-generation genetically modified (“GM”) crops, industry trade groups acknowledge that cross-pollination, adventitious commingling, and other “causes” make it virtually impossible to assure that any U.S. corn shipment is 100% non-GM. See VALUE ENHANCED GRAIN (VEG) SOLUTIONS, COMMENTARY: INTRODUCING VEG TO THE WORLD BIOTECH CONTROVERSY, at <http://www.vegrains.org/cgi-bin/english/Commentary%200802.cfm> (Aug. 22, 2002). Over and above

important safety issues have been sidelined in order to facilitate rapid growth of this nascent industry. First and foremost, readily available and far safer alternatives could be used instead of food crops for biopharm production. But, because market forces diverge from the public's interest on this point, those safer options have not been pursued. Without government action forcing innovation towards achieving public health ends, it is clear that these options will remain unexplored. At the very least, there should be a moratorium on field testing these crops until a host of health-related questions are answered. Among the most pressing questions are: Do biopharm residues bioaccumulate?²⁰ Is there a threshold below which these compounds can be safely consumed? Are there low-level, long-term health effects? Are these compounds allergens²¹ or toxins?²² Are biopharmed crops anti-nutrients?²³ How persistent are these compounds in the soil? How toxic are they to wildlife? How likely is the prospect that these non-food compounds could be spread to wild relatives?²⁴

any human health impacts, biopharm contamination of the food supply will likely have dramatic ramifications for the U.S. share of the global commodities market. *Id.*

²⁰ For this reason, opponents of biopharming refer to the practice as pharmageddon. *See, e.g.,* MAE-WAN HO, INSTITUTE OF SCIENCE IN SOCIETY, PHARMAGEDDON, at <http://www.i-sis.org.uk/Pharmageddon.php> (Dec. 2, 2002). Although this characterization is sensational, even those scientists closely affiliated with biopharm companies acknowledge that precautionary measures should be taken when biopharmaceuticals are likely to persist in the environment or bioaccumulate. *See, e.g.,* Henry Daniell et al., *Medical Molecular Farming: Production of Antibodies, Biopharmaceuticals and Edible Vaccines in Plants*, 6 TRENDS PLANT SCI. 219 (2001).

²¹ An allergic reaction is an abnormal response of the body's immune system to an otherwise safe compound. Some reactions are life threatening, such as anaphylactic shock. Some of the biopharm products currently under development have been engineered to produce trypsin. *See, e.g.,* U.S. Patent No. 6,087,558 (issued July 11, 2000) (claiming invention of a transgenic plant that produces trypsinogen—a precursor of trypsin). Trypsin has a history of eliciting allergic responses in exposed populations. For allergy information, see Harvey R. Colten et al., *Immediate Hypersensitivity to Hog Trypsin Resulting from Industrial Exposure*, 292 NEW ENG. J. MED. 1050 (1975); Peter R. Shewry et al., *Plant Protein Families and Their Relationships to Food Allergy*, 30 BIOCHEMICAL SOC. TRANSACTIONS 906 (2002) (identifying trypsin as an allergen). The poster child for inadvertent creation of allergenic products through genetic engineering involved the experimental transfer of a Brazil nut protein to soybeans. *See* Julie A. Nordlee et al., *Identification of a Brazil-nut Allergen in Transgenic Soybeans*, 334 NEW ENG. J. MED. 688 (1996).

²² A toxic reaction in humans is a response to a poisonous substance. Unlike allergic reactions, all humans are subject to toxic reactions. The Codex Alimentarius considers evaluations of allergenicity, toxicity, and anti-nutrient potential to be integral components of any food safety risk assessment process. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, CODEX PRINCIPLES AND GUIDELINES ON FOODS DERIVED FROM BIOTECHNOLOGY, at <ftp://ftp.fao.org/codex/standard/en/CodexTextsBiotechFoods.pdf> (last visited June 26, 2004).

²³ Anti-nutrients are naturally occurring compounds that interfere with absorption of important nutrients in digestion. For example, avidin, the first commercialized biopharm crop has a well-known ability to interfere with vitamin B absorption. U.S. Patent No. 5,767,379 (issued June 16, 1998) (claiming invention of a transgenic plant that produces avidin); *see also* MARK H. BEERS ET AL., MERCK MANUAL OF DIAGNOSIS AND THERAPY, sec. 1, ch. 3 (17th ed., John Wiley & Sons 1999), available at <http://www.merck.com/mrkshared/mmanual/section1/chapter3/3o.jsp>; Gianni Bregola et al., *Biotin Deficiency Facilitates Kindling Hyperexcitability in Rats*, 7 NEUROLOGICAL REPORT 1745 (1996) (inducing biotin deficiency by controlling avidin consumption); Claudia J. Carey & James G. Morris, *Biotin Deficiency in the Cat and the Effect on Hepatic Propionyl CoA Carboxylase*, 107 J. NUTRITION 330 (1977); Donald M. Mock et al., *Marginal Biotin Deficiency Is Teratogenic in ICR Mice*, 133 J. NUTRITION 2519 (2003); Toshiaki Watanabe, *Dietary Biotin Deficiency Affects Reproductive Function and Prenatal Development in Hamsters*, 123 J. NUTRITION 2101 (1993).

²⁴ In November 2003, a coalition of public interest groups filed suit in Hawaii District Court requesting an injunction barring future biopharm field tests until these questions are answered. Center for Food Safety v. Veneman, No. 03-1-1509 (D. Haw. Nov. 12, 2003), at <http://64.78.7.168/pubs/ComplaintHawaii11.12.2003.pdf>.

Unfortunately, under the U.S. fractured regulatory system, there is no way to pose these questions with regard to biopharm crops, let alone to answer them. Part of the problem is that no regulatory agency has a clear statutory mandate to regulate biopharming.²⁵ As a result, there are no coherent overarching government policies capable of ensuring that this new technology is safely explored and exploited.²⁶

The crisis is on our doorstep. According to some predictions, at least 10% of U.S. agricultural lands will be devoted to biopharming by the end of the decade.²⁷ Thousands of inedible and potentially harmful compounds may soon be grown in corn fields throughout the country. Without detailed and enforceable standards for responsible use of this new technology, it is inevitable that these biopharm crops will contaminate crops destined for use as human food.²⁸ The health risks from consuming these adulterated foods could be considerable.

Nevertheless, industry and governmental regulators have failed to impose obvious biological controls that would greatly protect the public's safety, while still permitting exploitation of this technology. For example, biopharming ought not be done in food crops, or, at the very least, ought not be released into the open environment of an agricultural field (as opposed to being grown in a greenhouse) before basic research has demonstrated that there will be no negative health effects from consuming contaminated foods.²⁹ Instead of adopting these sensible precautions, regulators have simply assumed that contamination can be avoided through use of physical containment measures. This wildly optimistic assumption is not shared by biopharm developers who admit that biopharm proteins will likely

²⁵ See *infra* Part II.B.

²⁶ Even Biotechnology Industry Organization ("BIO"), an industry trade and lobbying group, concedes that there is no United States policy on industrial biotechnology. See BIOTECHNOLOGY INDUSTRY ORGANIZATION, EXTERNAL RESOURCES, at www.bio.org/ind/links.asp (last visited June 26, 2004) (identifying four key publications that "represent, as close as you will find, a U.S. policy on industrial biotechnology"). In 2003, APHIS published interim guidelines for industrial biotechnology. *Introductions of Plants Genetically Engineered to Produce Industrial Compounds*, 68 Fed. Reg. 46,434 (Aug. 6, 2003). For the first time, these new regulations require that any such introductions be pursuant to a permit. At least 10 industrial biopharm field tests had already been conducted under a less stringent notification procedure. *Id.* at 46,435.

²⁷ See, e.g., Scott Kilman, *Food, Biotech Industries Feud: Crops Bred to Produce Medicines Raise Contamination Worries*, WALL ST. J., Nov. 5, 2002, at B7; Aaron Zitner, *Fields of Gene Factories*, L.A. TIMES, June 4, 2001, at A1; Biomass R&D Technical Advisory Committee, VISION FOR BIOENERGY & BIOBASED PRODUCTS IN THE UNITED STATES, at http://www.bioproducts-bioenergy.gov/pdfs/BioVision_03_Web.pdf (Oct. 2002).

²⁸ Indeed, in 2003, USDA found that about 20% of farmers growing existing genetically modified ("GM") crops failed to comply with planting regulations intended to prevent contamination of conventional crops. Emily Gersema, *USDA Survey Shows Biotech Rules Breaches*, ASSOCIATED PRESS, Sept. 10, 2003, available at 2003 WL 63460812. Given these high levels of non-compliance with existing requirements and relaxed regulatory oversight, there is no reason to believe that farmers' behavior will be any different with regard to biopharm crops. In addition, evidence of contamination is mounting. For example, after just two years of Canadian cultivation, GM canola has cross-pollinated so extensively that a new, triply herbicide resistant, feral canola has emerged. JIM ORSEN, GENE STACKING IN HERBICIDE TOLERANT OILSEED RAPE: LESSONS FROM THE NORTH AMERICAN EXPERIENCE, ENGLISH NATURE RESEARCH REPORTS NO. 443 (2002), available at <http://www.english-nature.org.uk/pubs/publication/PDF/enrr443.pdf>. In light of these findings, any regulatory decisions about these crops must assume that commingling will occur.

²⁹ The U.S. Environmental Protection Agency ("EPA") was advised to test transgenic plants producing pharmaceutical compounds for their biological effects at dietary concentrations which, at a minimum, will likely be encountered in the transgenic plant itself. See FIFRA SCIENTIFIC ADVISORY PANEL, MAMMALIAN TOXICITY ASSESSMENT GUIDELINES FOR PROTEIN PLANT PESTICIDES, SAP REPORT NO. 2000-03B (2000), available at <http://www.epa.gov/oscpmont/sap/2000/index.htm>. USDA does not require any such testing before permitting biopharm crops to be field-tested.

wind up in the food supply. Moreover, physical containment measures have not shown much success in existing GM crops.³⁰

The limited scope of existing biopharm regulation leaves the public unprotected and exposed to an unacceptable level of risk. Moreover, the mere threat of commingling may be enough to destroy the United States' multi-billion dollar export trade in corn and other commodities.³¹ These failures to address the problem of contamination and commingling become even more critical now that the Cartagena Protocol on Biosafety has entered into force.³² Article 10 of the Protocol gives states the power to refuse import of the products of biotechnology (called living modified organisms or LMOs in the Protocol) in order to avoid or minimize adverse effects on human health or the conservation and sustainable use of biological diversity.³³ It is hard to imagine anything more likely to justify a refusal to import under the Cartagena Protocol than undetectable commingling of industrial or pharmaceutical crops containing non-food proteins with export food crops. Protecting the public's interest in this context will require government to assume a far more active role than the hands-off attitude that has been the hallmark of conventional agricultural policy.

This Article raises a few of the more pressing public health questions that should be resolved before substantial portions of the nation's crop land are diverted from food production to biopharming. Part II provides an introduction to biopharming and outlines the various plans and projections for its commercial exploitation. Part III examines the existing regulatory structure, highlights some of its most critical weaknesses, and points out the serious risks this structure creates vis-à-vis the integrity of the food supply. Part IV articulates a central conclusion that safe and successful exploitation of these new technologies will demand a markedly different regulatory regime than the laissez-faire system that has prevailed in conventional agricultural policy. To that end, the final Part proposes some alternatives that would better safeguard public health while still permitting exploration of this exciting new technology.

³⁰ Physical containment measures involve using planting distances or timing to prevent contamination of conventional crops with GM crops. Unfortunately, for existing GM crops, physical containment measures have largely been ineffectual, either because the requirements are too lenient or because they are not being implemented. Indeed, a 2003 USDA survey found that about 20% of farms growing GM crops failed to comply with planting regulations intended to ensure physical containment. Gersema, *supra* note 28.

³¹ There is a zero tolerance level for unapproved genetically modified organisms. Corn is the largest U.S. crop, typically between 9-10 billion bushels annually. *See* CORN REFINERS ASSOCIATION, U.S. CORN PRODUCTION: 1999-2001, at <http://www.corn.org/web/uscpod.htm> (last visited June 26, 2004). Iowa, Illinois, Nebraska, and Minnesota alone produce more than 50% of the U.S. corn crop. U.S. GRAINS COUNCIL, WORLD CORN PRODUCTION AND TRADE, at <http://www.grains.org/grains/corn.html> (last visited June 26, 2004). Other major corn-producing states include Indiana, Wisconsin, South Dakota, Michigan, Missouri, Kansas, Ohio, and Kentucky. *Id.* In 2000, the United States grew 43% of the world's corn and is the single largest corn exporter, providing 64% of corn sold in the international corn market. *Id.*

³² The text of the CARTAGENA PROTOCOL ON BIOSAFETY is available at <http://www.biodiv.org/biosafety/protocol.asp> (last visited June 26, 2004). The Protocol entered into force on September 11, 2003 following the fiftieth ratification, by Palau. There are currently sixty members of the Protocol, including the European Union and other significant U.S. trading partners like Mexico. CARTAGENA PROTOCOL ON BIOSAFETY, STATUS OF RATIFICATION AND ENTRY INTO FORCE, Sept. 11, 2003, available at <http://www.biodiv.org/biosafety/signinglist.aspx?sts=rtf&ord=dt>.

³³ CARTAGENA PROTOCOL ON BIOSAFETY, *supra* note 32, at art. 10.

II. A BRIEF INTRODUCTION TO BIOTECHNOLOGY

Over centuries and millennia, humans have domesticated modified food crops in order to improve their agronomic and nutritional characteristics. For most of human agronomic history, this was a process of trial and error. Although it was clear that desirable agronomic traits could be inherited, there was no way to predict the outcome of a cross between any two particular plants. In 1865, an Augustinian monk named Gregor Mendel changed all that. Working with pea plants, Mendel deduced that offspring inherited traits from their parents in predictable patterns. His paper, *Versuche über Pflanzen-Hybriden* ("Experiments in Plant Hybridization"),³⁴ concluded that "heritable factors" (genes or alleles) come in pairs; segregate independently; and are governed by principles of dominance and recessiveness. Although the paper initially went unnoticed in scientific circles, these patterns of inheritance are now referred to as the Mendelian laws of genetics.

Armed with an understanding of Mendel's work, plant and animal breeders transformed agriculture. By systematically crossing and recrossing individuals with desirable characteristics, breeders were able to create new varieties that were more productive and easier to grow.³⁵

Almost a century later, James Watson and Francis Crick's 1953 paper, *A Structure for Deoxyribonucleic Acids*, described the structure of DNA—the molecule responsible for Mendelian inheritance.³⁶ This paper is generally considered to have ushered in the era of molecular genetics.³⁷ The discovery of the chemical structure of DNA opened up new vistas in biological and biochemical research.³⁸

By the early 1970's, Stanley Cohen and Hubert Boyer had built on Watson and Crick's work by successfully splicing a gene from one organism and moving it into another—the first use of recombinant DNA technology.³⁹ Suddenly researchers could move genes from one species to another, thus overcoming the reproductive

³⁴ For either the original text or an English translation, see ROGER B. BLUMBERG, TABLE OF CONTENTS FOR MENDEL'S PAPER AT MENDELWEB, at <http://www.mendelweb.org/MWpaptoc.html> (last visited June 26, 2004).

³⁵ For an excellent introduction to the basics of genetics from Mendel to modern biotechnology intended for high school students, see DNA FROM THE BEGINNING, at <http://www.dnafb.org/dnafb/> (last visited July 16, 2004). For further information on Mendel's role in modern genetics, geared to non-scientists, see MARANTZ HENIG, THE MONK IN THE GARDEN: THE LOST AND FOUND GENIUS OF GREGOR MENDEL, THE FATHER OF GENETICS (2000); MATT RIDLEY, GENOME: THE AUTOBIOGRAPHY OF A SPECIES IN 23 CHAPTERS (2000).

³⁶ J. D. Watson & F. H. C. Crick, *Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid*, 171 NATURE 737 (1953). Watson and Crick were awarded the 1962 Nobel Prize for this discovery. For a first-hand, and somewhat scandalous account of this discovery, see JAMES WATSON, THE DOUBLE HELIX: A PERSONAL ACCOUNT OF THE DISCOVERY OF THE STRUCTURE OF DNA (1968).

³⁷ No discussion of molecular genetics is complete without an acknowledgement of this groundbreaking work. See, e.g., Barbara R. Jasny & Leslie Roberts, *Building on the DNA Revolution: Introduction*, 300 SCIENCE 277 (2003) (stating that "[i]mages of Watson and Crick personified molecular biology to the general public in a way that has never been equaled"); Elizabeth Pennisi, *Building on the DNA Revolution: A Hothouse of Molecular Biology*, 300 SCIENCE 278 (2003) (discussing the work of Watson and Crick and later molecular genetics at the Laboratory of Molecular Biology at the University of Cambridge).

³⁸ See, e.g., Elizabeth Pennisi, *Building on the DNA Revolution: DNA's Cast of Thousands*, 300 SCIENCE 282 (2003) (discussing the landmark research on DNA and the genetic code after Watson and Crick).

³⁹ See, e.g., Stanley N. Cohen et al., *Construction of Biologically Functional Bacterial Plasmids In Vitro*, 70 PROC. NAT'L ACAD. SCI. U.S. 3240 (1973).

limits imposed by sexual incompatibility among species.⁴⁰ Recognizing the perils potentially associated with their new technique, Cohen and Boyer attempted to exercise some control over its uses.⁴¹

Cohen and Boyer's concerns about the potential hazards of these new techniques mirrored similar concerns that other researchers were expressing.⁴² In light of the as-yet-unassessed, but potentially harmful, consequences of this new research, the scientific community called for a voluntary moratorium on genetic engineering.⁴³ At a 1975 conference held at Asilomar Conference Center in Pine Grove, California, 150 scientists from around the world met to hammer out a set of safety precautions for genetic research.⁴⁴ Known as the Asilomar Consensus Statement, the conference recommended lifting the self-imposed moratorium and replacing it with guidelines for genetic engineering research.⁴⁵ The central assumption behind the consensus statement was that the unknown hazards of genetic engineering should be contained biologically and physically.⁴⁶ This consensus formed the basis for the Recombinant DNA Research Guidelines issued by the National Institutes of Health ("NIH") in 1976.⁴⁷

Until 1984, these guidelines, which applied to researchers funded by NIH, governed approval of DNA research. A successful legal challenge to decisions made under those guidelines forced the Reagan Administration to develop a more overarching regulatory policy to guide federal decision-making about biotechnology research and its products.⁴⁸ To that end, the Office of Science and Technology Policy issued the Coordinated Framework for Regulation of Biotechnology.⁴⁹ The

⁴⁰ See *id.* at 3244.

⁴¹ Stanley N. Cohen, *The Manipulation of Genes*, 233 SCI. AM. 25, 32 (1975).

⁴² See, e.g., Maxine Singer & Dieter Stoll, *Letter: Guidelines for DNA Hybrid Molecules*, 181 SCIENCE 1114 (1974).

⁴³ Paul Berg et al., *Letter: Potential Biohazards of Recombinant DNA Molecules*, 185 SCIENCE 303 (1974).

⁴⁴ For a recent account of that historic meeting, see Marcia Barinaga, *Asilomar Revisited: Lessons for Today?*, 287 SCIENCE 1584, 1585 (2000).

⁴⁵ Paul Berg et al., *Asilomar Conference on Recombinant DNA Molecules*, 188 SCIENCE 991, 991 (1975) ("... the evaluation of potential biohazards has proved to be extremely difficult. It is this ignorance that has compelled us to conclude that it would be wise to exercise considerable caution in performing this research.") [hereinafter Berg et al., *Asilomar Conference*]. For an interesting account of the self-regulatory project, see Judith P. Swazey et al., *Risks and Benefits, Rights and Responsibilities: A History of the Recombinant DNA Research Controversy*, 51 S. CAL. L. REV. 1019 (1978).

⁴⁶ Berg et al., *Asilomar Conference*, *supra* note 45, at 991; see also Paul Berg et al., *Summary Statement of the Asilomar Conference on Recombinant DNA Molecules*, 72 PROC. NAT'L ACAD. SCI. U.S. 1981, 1982 (1975) [hereinafter Berg et al., *Summary Statement*].

⁴⁷ See Recombinant DNA Research Guidelines, 41 Fed. Reg. 27,902, 27,903 (July 7, 1976). The guidelines, as updated, are still applicable to research funded by the National Institutes of Health ("NIH") or conducted at NIH and compliance with the guidelines is a condition for continued NIH funding. The 1976 guidelines prohibited six types of rDNA experiments until more could be learned, allowed other rDNA experiments to proceed only under strict safety standards, required the physical or biological containment of rDNA recombinants in the laboratory, and prohibited the deliberate release of rDNA organisms into the outside environment until more could be learned. Peer review was the primary means to ensure that these guidelines were carried out. *Id.* at 27,902-21.

⁴⁸ *Found. on Econ. Trends v. Heckler*, 756 F.2d 143, 151 (D.C. Cir. 1985) (describing the evolution of the guidelines and upholding an injunction barring deliberate release of a genetically modified organism known as "ice-minus" until NIH completed an adequate environmental impact statement).

⁴⁹ Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. 23,302 (June 26, 1986).

Framework purported to describe the comprehensive federal regulatory policy for ensuring the safety of biotechnology research and products.⁵⁰ The Framework announced that no new laws would be needed to respond to challenges posed by this new technology.⁵¹ Instead, products of biotechnology would be regulated under existing laws based on their intended use; thus, food would be regulated under the Federal Food, Drug, and Cosmetic Act,⁵² pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act,⁵³ agricultural plants under the Plant Protection Act,⁵⁴ and so on.⁵⁵ One unfortunate consequence of this reliance on existing law has been an erosion, over time, of the commitment to biological containment measures.

During the 1980s, researchers developed bioengineering methods to integrate foreign DNA permanently into plant genomes, enabling the production of transgenic plants expressing a wide variety of foreign genes.⁵⁶ In a process called transformation,⁵⁷ genes coding for a specific trait can be isolated from any organism and inserted into the embryos of any food crop.⁵⁸ The transformed embryos are then grown into adult plants that express the newly added trait. Through bioengineering, researchers have been able to manipulate plants in unprecedented fashions and to sequence a series of plant genomes.⁵⁹ Information gleaned from this new technology opened up immense possibilities for agriculture and began the rapid cascade of scientific progress that I call “the ag-biotech revolution.”

The first bioengineered, or GM crops were commercialized in 1996. By 2001 U.S. farmers were devoting approximately 88 million acres to GM crops⁶⁰—the

⁵⁰ For a thorough description of the Framework and its development, see D. L. Uchtmann, *StarLink™—A Case Study of Agricultural Biotechnology Regulation*, 7 DRAKE J. AGRIC. L. 159 (2002).

⁵¹ *Id.* at 169.

⁵² Federal Food, Drug, and Cosmetic Act (“FFDCA”), 21 U.S.C. §§ 301 et seq. (2000).

⁵³ Federal Insecticide, Fungicide, and Rodenticide Act (“FIFRA”), 7 U.S.C. §§ 121 et seq. (2000).

⁵⁴ Plant Protection Act (“PPA”), 7 U.S.C. §§ 7701 et seq. (2000).

⁵⁵ Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. at 23,302 (June 26, 1986).

⁵⁶ Jozef St. Schell, *Transgenic Plants as Tools to Study the Molecular Organization of Plant Genes*, 237 SCIENCE 1176, 1176-83 (1987).

⁵⁷ There are three primary means to transform, or genetically modify, plants. The most common takes advantage of the unique properties of *Agrobacterium tumefaciens*, a soil bacteria that infects plants by transferring a plasmid of its own DNA into the target plant. By modifying the genes contained in this plasmid, *A. tumefaciens* infection can be a means to deliver desirable genes into plant cells instead of the bacteria’s own infective genes, which cause Crown Gall disease. Because *A. tumefaciens* is a known plant pest, these transformations fall neatly within USDA’s regulatory authority as outlined in the PPA, 7 U.S.C. §§ 7701-7772. By contrast, USDA authority over the other primary methods of transforming plants, the “biolistics” or “gene gun” method and electroporation are less clear. These are the various techniques that I will refer to as genetic engineering, bioengineering, genetic modification, or biotechnology.

⁵⁸ For a lay description of this process, complete with pictures, see, PARTNERSHIP FOR PLANT GENOMICS EDUCATION, UNIVERSITY OF CALIFORNIA, DAVIS, PLANT TRANSFORMATION, at <http://ceprap.ucdavis.edu/Transformation/transform1.htm> (last updated Apr. 29, 2003).

⁵⁹ There are plant DNA libraries for more than thirty important crops. U.S. NATIONAL AGRICULTURE LIBRARY, USDA, PLANT DNA LIBRARY, at <http://www.nal.usda.gov/pgdic/dnalibr/> (last visited June 26, 2004). There are almost one hundred plant DNA mapping projects around the world. U.S. NATIONAL AGRICULTURE LIBRARY, USDA, PLANT GENOME MAPPING PROJECTS, at http://www.nal.usda.gov/pgdic/Map_proj/ (last visited June 26, 2004). In 2000, the entire *Arabidopsis* genome (a plant widely used as a model plant organism) was sequenced. THE ARABIDOPSIS INFORMATION RESOURCE, at <http://www.arabidopsis.org/> (last updated Mar. 30, 2004).

⁶⁰ Proposed Federal Actions to Update Field Test Requirements for Biotechnology Derived Plants and to Establish Early Food Safety Assessments for New Proteins Produced by Such Plants, 67 Fed. Reg. at 50,587 (Aug. 2, 2002).

lion's share of the 130 million GM acres planted worldwide.⁶¹ In 2003, 73% of the cotton, 81% of the soybeans, and 40% of the corn planted in the United States were GM varieties.⁶² Biotech research has grown at an even more explosive rate. In 1994, approximately 7,000 acres in the United States were planted with 593 biotech field tests; in 2001, there were 57,000 experimental acres planted with 1,117 field tests.⁶³ While most of these were field tests of first-generation GM crops (those engineered for herbicide resistance or to produce endogenous pesticides), some 300 were biopharm crops.⁶⁴

A. BIOPHARMING 101

During the 1990s, researchers around the world embarked on the most ambitious biotechnology project ever—the sequencing of the human genome.⁶⁵ The Human Genome Project⁶⁶ and related biomedical research spawned a generation of highly specialized drugs based on antigens (vaccines), recombinant proteins (biologics) and human antibodies (collectively “therapeutics”).⁶⁷ Demand for therapeutics is growing rapidly, especially those designed for chronic illnesses like psoriasis, allergic asthma, and rheumatoid arthritis.⁶⁸ Meeting the projected demand for these therapeutics will require thousands of kilograms of purified proteins.⁶⁹

Commercial production of these products currently relies on abiotic fermentation (primarily in *E. coli* or yeast) or on mammalian cell culture (primarily in Chinese hamster ovary cells (“CHO cells”)).⁷⁰ These expression systems have some serious drawbacks: they tend to be expensive, labor intensive, and they produce relatively low yields that fall short of supplying all patients in need. Generally, recombinant mammalian systems can produce about 1-4 grams of a therapeutic protein per liter of media every 2-3 weeks,⁷¹ while recombinant *E. coli* systems yield 1-4 grams per liter every 1-2 days.⁷² Recombinant monoclonal antibody culture in CHO cells yields .5-1 gram per liter per day, and mammalian cell

⁶¹ *Id.* The increases are most dramatic in the United States, but Canada, Argentina, and China have also experienced significant growth in the development and use of biotechnology-derived crops.

⁶² See ECONOMIC RESEARCH SERVICE, USDA, ADOPTION OF GENETICALLY ENGINEERED CROPS IN THE U.S., at <http://www.ers.usda.gov/Data/BiotechCrops/adoption.htm> (last updated Sept. 10, 2003).

⁶³ See 67 Fed. Reg. at 50,587.

⁶⁴ See BILL FREESE, MANUFACTURING DRUGS AND CHEMICALS IN CROPS: BIOPHARMING POSES NEW THREATS TO CONSUMERS, FARMERS, FOOD COMPANIES AND THE ENVIRONMENT (2002), available at http://www.foe.org/safefoods/BIOPHARM_FACTSHEET.doc. Between 1989 and July 2003, APHIS considered 170 permit applications—162 permits were issued, 7 were withdrawn, and 1 is still pending. No applications were denied.

⁶⁵ A complete sequence of the human genome was announced in April 2003. NATIONAL HUMAN GENOME RESEARCH INSTITUTE, at <http://www.genome.gov> (last visited June 26, 2004).

⁶⁶ For information about the human genome project, see OFFICE OF SCIENCE, DOE, BIOLOGICAL & ENVIRONMENTAL RESEARCH, HUMAN GENOME RESEARCH, at http://www.science.doe.gov/ober/hug_top.html (last visited June 26, 2004).

⁶⁷ *Id.*

⁶⁸ Stephan Herrera, *Protein Therapy Could Heal Agbio*, RED HERRING, Sept. 15, 2001, available at http://www.agbioworld.org/biotech_info/articles/interviews/protein_therapy.html.

⁶⁹ *Id.*

⁷⁰ See C.L. Cramer et al., *Transgenic Plants for Therapeutic Proteins: Linking Upstream and Downstream Strategies*, 240 CURR. TOP. MICROBIOL. IMMUNOL. 95 (1999).

⁷¹ All of the production figures in this paragraph come from RONALD A. RADER, BIOPHARMA: BIOPHARMACEUTICAL PRODUCTS IN THE U.S. MARKET 17 (2d ed. 2003).

⁷² *Id.*

perfusion bioreactor systems yield about .3 gram per liter each day.⁷³ Biopharming represents the cutting edge of the research on increasing yields with at least 120 different research institutions currently developing a staggering array of biopharm products.⁷⁴

At least in theory, plants can be engineered to express high levels of the desired pharmaceutical protein.⁷⁵ One 200-acre biopharm field could therefore produce significantly greater quantities of therapeutics than current methods. Moreover, biopharm crops offer some other distinct advantages for producing pharmaceutical proteins. Large-scale biopharming of these compounds should be more economical than current production techniques that rely on mammalian cell cultures. Because biopharming can be done by ordinary farmers in ordinary fields, rather than by highly skilled workers in high-tech facilities, the capital investment costs are relatively low.⁷⁶ Some estimates indicate that biopharming could reduce production costs for these therapeutics by an order of magnitude.⁷⁷ Biopharming can also draw on a wealth of existing agronomic experience with growing, harvesting and processing these crops in their conventional forms. Unlike CHO cell or E. coli production techniques, biopharming does not require a highly educated and tech-savvy workforce. Biopharmed therapeutics may also be safer than those produced via existing techniques, because plant-produced therapeutics have a reduced risk of carrying human pathogens.⁷⁸

The range of possible biopharm products under development is truly staggering.⁷⁹ For example, researchers at the Washington State University have transformed barley so that it produces α_1 -antitrypsin, a human blood plasma protein used to treat cystic fibrosis and various skin diseases.⁸⁰ Barley has also been transformed to produce Antithrombin III, a human anticoagulant.⁸¹ There has been a great deal of research on antibody production in biopharm plants, so-called

⁷³ *Id.*

⁷⁴ Introductions of Plants Genetically Engineered to Produce Industrial Compounds, Interim Rule, 68 Fed. Reg. at 46,434 (Aug. 6, 2003) (indicating that roughly half of the entities are private companies and half are research institutes).

⁷⁵ For example, avidin is expressed at 1.5-3% of total soluble protein in corn seeds. Elizabeth E. Hood et al., *Commercial Production of Avidin from Transgenic Maize: Characterization of Transformant, Production, Processing, Extraction and Purification*, 3 MOLECULAR BREEDING 291, 292 (1997). Chloroplast transformation could potentially increase that yield by an order of magnitude. See Daniell, *supra* note 8.

⁷⁶ Stephen J. Streatfield et al., *Plant-based Vaccines: Unique Advantages*, 19 VACCINE 2742 (2001); Takeshi Arakawa et al., *Expression of Cholera Toxin B Subunit Oligomers in Transgenic Potato Plants*, 6 TRANSGENIC RESEARCH 403, 412 (1997) (describing biopharming as safer and more cost effective).

⁷⁷ FREESE, *supra* note 64; see also James W. Larrick et al., *Production of Secretory IgA Antibodies in Plants*, 18 BIOMOLECULAR ENGINEERING 87, 90, 92 (2001).

⁷⁸ For a description of the state of the industry, and a detailed assessment of the advantages of plant-based production of therapeutics, see Cramer, *supra* note 70.

⁷⁹ *Id.* at 97 (putting forth a partial list of biopharm products under development).

⁸⁰ See Henriette Horvath et al., *The Production of Recombinant Proteins in Transgenic Barley Grains*, 97 PROC. NAT'L ACAD. SCI. U.S. 1914 (2000). For a detailed description of the transformation, see Diter von Wettstein, Application for Permit #00-334-01R Renewal under 7 C.F.R. § 340 (Apr. 30, 2002) (on file with author). Currently this protein is available in limited supply from human blood plasma. If biopharming successfully increases the supply, α_1 -antitrypsin could be used to treat a wide range of disorders more effectively. *Id.* at 5.

⁸¹ von Wettstein, *supra* note 80, at 5.

“plantibodies,”⁸² and various research teams have demonstrated the possibilities of growing biovaccines against infectious diseases like cholera,⁸³ hepatitis B,⁸⁴ Norwalk virus,⁸⁵ and traveler’s diarrhea.⁸⁶ Pre-clinical trials for these biovaccines have demonstrated that plant-grown vaccines can be effective in humans.⁸⁷ Researchers at ProdiGene and Epicyte have transformed corn to produce human monoclonal antibodies to treat HIV,⁸⁸ and herpes simplex,⁸⁹ and a team at Cornell has developed individualized biovaccines to treat non-Hodgkin’s lymphoma.⁹⁰ ProdiGene currently biopharms avidin corn for use as a research grade chemical,⁹¹ and Epicyte has developed a corn-grown spermicidal plantibody that it hopes to market as a contraceptive.⁹²

Although biopharm research has been conducted on a wide variety of plant species, corn has become the crop of choice for biopharm companies looking to commercialize their products.⁹³ Indeed, the number of corn field tests dwarfs experimentation in all other crops combined.⁹⁴ Corn does offer a number of advantages—particularly the utility of corn cobs as a pre-packaged, cheap, and easily transported storage system. Unfortunately, this use of corn raises some serious safety questions because of the likelihood of contaminating the food supply. Corn is, after all, a promiscuously outcrossing, wind-pollinated plant.⁹⁵ Although

⁸² Daniell et al., *supra* note 20, at 221, fig. 1 (2001) (describing current human and mammalian trials of these plantibodies).

⁸³ Arakawa et al., *supra* note 76.

⁸⁴ Jozef Kapusta et al., *A Plant-derived Edible Vaccine Against Hepatitis B Virus*, 13 FASEB J. 1796 (1999).

⁸⁵ Carol O. Tacket et al., *Human Immune Responses to a Novel Norwalk Virus Vaccine Delivered in Transgenic Potatoes—Concise Communication*, 182 J. INFECTIOUS DISEASES 302, 302-05 (2000).

⁸⁶ Carol O. Tacket et al., *Immunogenicity in Humans of a Recombinant Bacterial Antigen Delivered in a Transgenic Potato*, 4 NATURE MED. 607 (1998).

⁸⁷ *Id.*; Kapusta et al., *supra* note 84. For a discussion of another experiment with a biovaccine, see Anna Modelska et al., *Immunization Against Rabies With Plant-Derived Antigen*, 95 PROC. NAT’L ACAD. SCI. U.S. 2481 (1998).

⁸⁸ See BIOEXCHANGE, EPICYTE PHARMACEUTICAL ADVANCES PRODUCTION OF HUMAN HIV ANTIBODIES IN PLANTS (Jan. 28, 2003), available at http://www.bioexchange.com/news/news_page.cfm?id=16071; see generally Biolex, Inc., at <http://www.biolex.com> (Biolex, Inc. acquired Epicyte Pharmaceutical Inc.).

⁸⁹ Larry Zeitlin et al., *A Humanized Monoclonal Antibody Produced in Transgenic Plants for Immunoprotection of the Vagina Against Genital Herpes*, 16 NATURE BIOTECHNOLOGY 1361 (1998).

⁹⁰ Alison A. McCormick et al., *Rapid Production of Specific Vaccines for Lymphoma by Expression of the Tumor-derived Single-chain Fv Epitopes in Tobacco Plants*, 96 PROC. NAT’L ACAD. SCI. U.S. 703 (1999).

⁹¹ Elizabeth E. Hood, et al, *Commercial Production of avidin from transgenic maize: characterization of transformant, production, processing, extraction and purification*, 3 MOLECULAR BREEDING 291-306 (1997).

⁹² See Topical Application of Antibodies for Contraception and for Prophylaxis Against Sexually Transmitted Diseases, U.S. Patent No. 6,355,235 (issued Mar. 12, 2002) (describing the antibodies as extremely effective in small doses), available at http://www.pharmcast.com/Patents/040400OG/6045786_sexuallyTran040400.htm.

⁹³ See FREESE, *supra* note 64.

⁹⁴ *Id.* (reporting that 134 of USDA’s 198 biopharm field trial notifications or permits were for corn).

⁹⁵ For an explanation of corn’s reproductive behavior, see U.S. ENVIRONMENTAL PROTECTION AGENCY, PESTICIDE FACT SHEET: BACILLUS THURINGIENSIS SUBSPECIES CRY1F PROTEIN AND THE GENETIC MATERIAL NECESSARY FOR ITS PRODUCTION (PLASMID INSERT PHI 8999) IN CORN, at http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_006481.pdf (last visited July 23, 2004).

companies routinely claim that test site locations are confidential business information ("CBI"),⁹⁶ rendering that information unavailable to the public, much of this testing apparently occurred in the Corn Belt.⁹⁷

B. U.S. POLICY TOWARDS BIOPHARMING

Biopharming is an integral part of President Bush's energy policy and associated initiatives and was strongly supported by President Clinton before him.⁹⁸ In 2000, Congress passed the Biomass Research and Development Act,⁹⁹ which created an interagency Biomass Research and Development Board and a Biomass Research and Development Technical Advisory Committee.¹⁰⁰ In 2002, the Advisory Committee published a National Vision Statement and a Biomass Roadmap for bioenergy and biobased products.¹⁰¹ The Vision Statement sets a goal of satisfying 18% of the 2010 production target of chemical commodities through biobased production.¹⁰² One of the articulated, and oft-repeated goals of the Vision Statement and its accompanying Roadmap was "remov[al of] the barriers facing biomass technologies."¹⁰³ The Committee's charge extends to all biobased industries, including biopharming.¹⁰⁴

Although this Committee was a joint project between the Departments of Energy and Agriculture, the Vision Statement and Biomass Roadmap were emphatically a product of the interested industries. Perhaps not surprisingly, the tenor of the Committee's public policy recommendations was to support and facilitate development of biobased industry and to downplay any drawbacks.¹⁰⁵ Missing from these recommendations is any discussion of the very serious public health¹⁰⁶ and environmental¹⁰⁷ concerns posed by this new technology.

In shelving these concerns in favor of promoting industrial "progress," the Committee was merely continuing a tradition that had earlier been established by the

⁹⁶ ENVIRONMENTAL EFFECTS, *supra* note 14, at 11 (noting that the extent of confidential business information claimed by registrants "hampers external review and transparency of the decision-making process").

⁹⁷ See FREESE, *supra* note 64.

⁹⁸ GENET, HOW THE BIOTECH INDUSTRY CAPTURED WASHINGTON'S ATTENTION, at <http://www.gene.ch/genet/2003/Jul/msg00049.html> (July 9, 2003).

⁹⁹ Biomass Research and Development Act, Title III of the Agricultural Risk Protection Act, Pub. L. No. 106-224 (2000).

¹⁰⁰ *Id.*

¹⁰¹ See BIOMASS RESEARCH AND DEVELOPMENT TECHNICAL ADVISORY COMMITTEE, DOE, VISION FOR BIOENERGY & BIOBASED PRODUCTS IN THE UNITED STATES, at <http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf> (Oct. 2002) [hereinafter DOE VISION FOR BIOENERGY]; BIOMASS RESEARCH AND DEVELOPMENT TECHNICAL ADVISORY COMMITTEE, DOE, ROADMAP FOR BIOMASS TECHNOLOGIES IN THE UNITED STATES, at <http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf> (Dec. 2002) [hereinafter DOE BIOMASS ROADMAP].

¹⁰² DOE VISION FOR BIOENERGY, *supra* note 101, at ¶ 3.

¹⁰³ *Id.* at ¶ 5.

¹⁰⁴ Pub. L. No. 106-224.

¹⁰⁵ DOE VISION FOR BIOENERGY, *supra* note 101; DOE BIOMASS ROADMAP, *supra* note 101.

¹⁰⁶ The potential for these non-food proteins to render otherwise unidentifiable foods either allergenic or toxic to consumers is the most prominent of these public health concerns. Because biopharm crops look exactly like conventional crops, a consumer will have no way to know if she is inadvertently consuming dangerous compounds.

¹⁰⁷ For example, the National Research Council ("NRC") has suggested that large-scale biobased production would necessitate withdrawing half the land currently fallow under the Conservation Reserve Program. See COMMITTEE ON BIOBASED INDUSTRIAL PRODUCTS, *supra* note 10, at 4.

Department of Energy (“DOE”). In 1998, the Department of Energy’s Office of Industrial Technology (“OIT”) sponsored the Agricultural Industries of the Future as a public/private collaboration to plan the future of industrial biopharming.¹⁰⁸ This group produced two critical documents: a strategic vision entitled Plant/Crop Based Renewable Resources 2020¹⁰⁹ and the Technology Roadmap for Plant/Crop-Based Renewable Resources 2020.¹¹⁰ The Technology Roadmap set a target that, by 2020, 10% of all chemical feedstock demand be satisfied through biopharming.¹¹¹ DOE made it clear that the Technology Roadmap was “driven by industry” and that OIT’s role was to “support the development and deployment of technologies that will shape the future of the agriculture industry.”¹¹² Indeed, agencies unambiguously described the Vision Statement and the Biomass Roadmap as articulating the industries’ vision for their future.¹¹³

The Technology Roadmap was intended to “encourage industry to undertake long-term, sector-wide technology planning.”¹¹⁴ Conspicuously absent from this long-term, sector-wide planning is any consideration of the serious threats that improperly managed biopharm crops will pose to the U.S. food supply. Protecting the integrity of the food supply is not among the priorities identified in the Roadmap, and environmental protection is thrown in as an afterthought.¹¹⁵ No consumer or environmental non-government organizations, no public health experts, and for that matter no Food and Drug Administration (“FDA”) or Environmental Protection Agency (“EPA”) officials participated in the workshops that produced the Roadmap.¹¹⁶ The only U.S. Department of Agriculture (“USDA”) officials were from the Agricultural Research Service,¹¹⁷ USDA’s in-house biopharm research arm.

¹⁰⁸ DOE, AGRICULTURE COMPACT, at <http://www.oit.doe.gov/agriculture/compact.shtml> (last updated Jan. 30, 2004).

¹⁰⁹ OFFICE OF INDUSTRIAL TECHNOLOGIES, DOE, PLANT/CROP BASED RENEWABLE RESOURCES 2020, at http://www.oit.doe.gov/agriculture/pdfs/ag_vision.pdf.

¹¹⁰ OFFICE OF INDUSTRIAL TECHNOLOGIES, DOE, TECHNOLOGY ROADMAP FOR PLANT/CROP-BASED RENEWABLE RESOURCES 2020, DOE/GO 10099-385, 27 (1999), at http://www.oit.doe.gov/agriculture/pdfs/technology_roadmap.pdf [hereinafter DOE TECHNOLOGY ROADMAP].

¹¹¹ *Id.* at 10. Despite being available from the DOE website and various other indicia of government sanction (including participation of DOE and USDA officials), DOE describes the Technology Roadmap as a process initiated by the National Corn Growers Association, and produced by organizations representing the U.S. agricultural, forestry, and chemical companies. DOE, VISIONS AND ROADMAPS, at <http://www.oit.doe.gov/agriculture/visions.shtml> (last updated Jan. 30, 2004) [hereinafter DOE VISIONS AND ROADMAPS].

¹¹² *Id.*

¹¹³ DOE, INDUSTRIAL TECHNOLOGIES PROGRAM: AGRICULTURE, at <http://www.oit.doe.gov/agriculture> (last updated Jan. 30, 2004).

¹¹⁴ *Id.* DOE VISIONS AND ROADMAPS, *supra* note 111.

¹¹⁵ DOE TECHNOLOGY ROADMAP, *supra* note 110.

¹¹⁶ *Id.* at app. 5.

¹¹⁷ The Agricultural Research Service (“ARS”) is the in-house research agency of the U.S. Department of Agriculture. ARS conducts extensive biopharm research focusing on:

“developing feedstocks and industrial products, including biofuels and bioenergy, that expand markets for agricultural materials, replace imports and petroleum-based products, and offer opportunity to meet environmental needs. This includes developing, modifying and utilizing new and advanced technologies to convert plant and animal commodities and by-products to new products and by developing energy crops as well as new crops to meet niche market opportunities.”

This description of ARS is available at USDA, BBCC MEMBER AGENCIES, AGRICULTURAL RESEARCH SERVICE, at http://www.ars.usda.gov/Bbcc/usda_BBCC.htm (last updated Sept. 11, 2003). Given ARS’s mandate, it is difficult to imagine the agency as a voice for caution in the Roadmap process.

No Animal and Plant Health Inspection Service (“APHIS”) officials experienced in the logistical problems of trying to prevent cross-contamination and commingling of agricultural crops were invited to participate.

It was a serious mistake to exclude these important stakeholders from the “long-term sector-wide” planning process. The Vision Statements and Roadmaps produced under these circumstances were seriously flawed and are unable to cope with the very real problems posed by biopharming.

III. REGULATORY GAPS AND BIOPHARMING

USDA has little experience or familiarity with the non-food compounds involved in biopharming,¹¹⁸ some of which are known to have deleterious effects on human health. For example, the first commercialized biopharm crop is a corn plant engineered to produce industrial grade avidin, a diagnostic reagent isolated from chicken egg.¹¹⁹ Avidin is known to cause vitamin B deficiency upon excessive ingestion.¹²⁰ The National Academy of Science has been extremely critical of USDA’s handling of avidin corn, calling it an example of lax and inadequate regulation.¹²¹ Other biopharm crops similarly produce compounds not intended for consumption as food; indeed, many are intended for oral delivery of medicines.

There has been little assessment of the potential health impacts from food contaminated with these or any other biopharm crops.¹²² Despite a clear likelihood that people will ingest these antibodies, plastics, and vaccines with their cornflakes, we have no knowledge about the health effects of consuming these compounds.¹²³ Exposure through ingestion raises serious questions that should be answered before these crops are commercialized and grown in uncontrolled conditions. Unfortunately, this means of exposure falls entirely outside the existing regulatory scheme and is completely unregulated.¹²⁴ Because the biopharm crops are not intended for food, they fall entirely outside FDA’s regulatory authority.¹²⁵ Nor does USDA evaluate the health effects of contamination in its permit process. Instead, USDA imposes a series of physical containment measures on these crops and then assumes that these measures will prevent contamination of the food supply.¹²⁶ This reliance on physical containment measures flies in the face of all available information about how such measures actually work.

¹¹⁸ Introduction of Plants Genetically Engineered to Produce Industrial Compounds, 68 Fed. Reg. 46,434 (Aug. 6, 2003).

¹¹⁹ Hood et al., *supra* note 75.

¹²⁰ See FREESE, *supra* note 64.

¹²¹ ENVIRONMENTAL EFFECTS, *supra* note 14, at 180-82.

¹²² See Press Release, Genetically Engineered Food Alert Campaign Center, EPA Gears Up to Approve Controversial Bt Corn Without Conducting Human Health Studies (Oct. 11, 2001), available at http://www.gefoodalert.org/library/admin/uploadedfiles/EPA_Gears_Up_to_Approve_Controversial_Bt_Corn_.htm.

¹²³ See *id.*

¹²⁴ See The New Farm, *U.S. Not Prepared to Monitor Approved Biotech*, ENVIRONMENTAL NEWS SERVICE, April 25, 2003, available at http://www.newfarm.com/news/050103/0501/biotech_monitor.shtml.

¹²⁵ Drugs produced through biopharming are, however, subject to the same regulatory regime as drugs produced by conventional means.

¹²⁶ For USDA’s regulatory plan, see 7 C.F.R. § 340.4 (2003); Field Testing of Plants Engineered to Produce Pharmaceutical and Industrial Compounds, 68 Fed. Reg. 11,337 (Mar. 10, 2003).

A. PAST AS PROLOGUE: THE BIOTECH INDUSTRY'S UNSUCCESSFUL PAST ATTEMPTS AT PHYSICAL CONTAINMENT

Although few biopharm crops have been commercialized, the first generation of GM crops have been planted commercially for the past six years—enough time to develop some sense of how well required physical containment measures are being implemented for those crops. Unfortunately, industry's track record on successfully containing GM crops remains singularly unimpressive. A series of near-miss disasters has undermined public confidence in existing regulatory processes.

StarLink corn is by far the most famous example of how poorly physical containment measures prevent contamination of the food supply when a food crop is genetically modified in a manner that precludes its use as food.¹²⁷ StarLink corn was genetically engineered to produce Bt toxin,¹²⁸ a pesticide toxic to some common lepidopteran pests.¹²⁹ Because of the particular nature of the genetic transformation involved in creating StarLink corn,¹³⁰ there were unanswered questions about whether StarLink corn was a human allergen.¹³¹ As a result of these allergenicity concerns, StarLink corn was not approved for use as human food.¹³² In order to get permission to market StarLink corn for animal feed or industrial uses, its manufacturer assured government regulators that the corn would be kept out of the human food supply.¹³³

In September of 2000, however, a coalition of environmental groups announced they had discovered StarLink corn in twenty-three common grocery products.¹³⁴ The announcement set off a frenzy of product recalls and consumer panic.¹³⁵ Ultimately, the unapproved and possibly dangerous corn was discovered in more

¹²⁷ See Rebecca M. Bratspies, *Myths of Voluntary Compliance: Lessons from the StarLink Corn Fiasco*, 27 WM. & MARY ENVTL. L. & POL'Y REV. 593, 628-33 (2003); MANDEL, *supra* note 16.

¹²⁸ StarLink corn was genetically engineered to contain two novel genes—one conveying herbicide tolerance and one conveying insect resistance. Uchtmann, *supra* note 50, at 160. The herbicide tolerance gene was the product of an earlier approval process. It was the addition of a gene derived from the bacterial species *Bacillus thuringiensis* (Bt), coding for an insecticidal protein called Cry9C, that triggered the StarLink crisis. *Id.* at 160, 174-75.

¹²⁹ Lepidoptera is a large order of insects, comprised of butterflies and moths. For a description of the biological mechanism by which Bt kills Lepidopteran pests, see INTERNATIONAL LIFE SCIENCE INSTITUTE, AN EVALUATION OF INSECT RESISTANCE MANAGEMENT IN BT FIELD CORN: A SCIENCE BASED FRAMEWORK FOR RISK ASSESSMENT AND RISK MANAGEMENT 9-10 (1998), available at http://www.ilsa.org/file/h5_IRM.pdf.

¹³⁰ Cry9C, the Bt protein incorporated into StarLink corn, shared properties with some known food allergens. See NATIONAL CENTER FOR ENVIRONMENTAL HEALTH, CDC, INVESTIGATION OF HUMAN HEALTH EFFECTS ASSOCIATED WITH POTENTIAL EXPOSURE TO GENETICALLY MODIFIED CORN, at <http://www.cdc.gov/nceh/ehhe/Cry9cReport> (June 11, 2001) [hereinafter CDC REPORT].

¹³¹ Marc Kaufman, *Biotech Critics Cite Unapproved Corn in Taco Shells: Gene-Modified Variety Allowed Only for Animal Feed Because of Allergy Concerns*, WASH. POST, Sept. 19, 2000, at A2.

¹³² Approval of Pesticide Product Registrations, 63 Fed. Reg. 28,258 (May 22, 1998).

¹³³ Matt Crenson, *Rules for Genetically Modified Corn Broke Down Between Seed Plant, Farm*, ST. LOUIS POST-DISPATCH, Dec. 15, 2000, at A10.

¹³⁴ *StarLink Corn: How it Reached the Food Supply*, ASSOCIATED PRESS, Dec. 4, 2000, available at <http://archive.showmenews.com/2000/dec/20001204busi011.asp>; see also, Rebecca M. Bratspies, *Myths of Voluntary Compliance: Lessons from the StarLink Corn Fiasco*, 27 WM. & MARY ENVTL. L. & POL'Y REV. 593, 628-33 (2003).

¹³⁵ See, e.g., Associated Press, *Biotech Corn Recall Expands in Stores, Restaurants*, WASH. POST, Nov. 3, 2000, at A5; Mark Kaufman, *Corn Woes Prompt Kellogg Plant Shutdown*, WASH. POST, Oct. 21, 2000 at A2; *Western Family Recalls Products with Altered Corn*, PORTLAND OREGONIAN, Oct. 26, 2000, at A2.

than 300 types of processed foods that had to be pulled from grocery shelves around the world.¹³⁶ Under heavy pressure from USDA, StarLink's manufacturer, Aventis, contacted growers and repurchased their remaining StarLink corn to ensure that no more of it entered the food supply.¹³⁷ These efforts were relatively successful and most of the StarLink crop was removed from the food supply.¹³⁸ Although there was a "medium likelihood" that StarLink corn was allergenic,¹³⁹ the anti-GM activists had caught the contamination before much non-food corn had entered the food supply.¹⁴⁰ Therefore, the Centers for Disease Control and FDA concluded that based on the low exposure there was only a "low probability" that consumers would actually develop allergies to it.¹⁴¹

Even so, the StarLink fiasco had a devastating effect on consumer confidence in biotechnology and raised troubling questions about whether the integrity of the food supply is adequately protected.¹⁴² After all, it was only because GM opponents independently tested packaged corn foods for StarLink contamination and then gave their discovery of contamination so much publicity that so little StarLink corn made it into the food supply. That fortunate situation owed nothing to the effectiveness of regulatory oversight. The crisis also devastated U.S. grain exports.¹⁴³

Another notorious incident involved two biopharm corn test plots planted by one of biopharming's leading companies, ProdiGene. ProdiGene was the first

¹³⁶ U.S. FOOD & DRUG ADMINISTRATION, ENFORCEMENT REPORT, at <http://www.fda.gov/bbs/topics/ENFORCE/ENF00666.html> (Nov. 1, 2000). Millions of bushels of StarLink corn had been commingled with food corn in at least 350 grain elevators. Kurt Eichenwald, *New Concerns Rise on Keeping Track of Modified Corn*, N.Y. TIMES, Oct. 14, 2000, at A1.

¹³⁷ News Release, USDA, Statement by the U.S. Department of Agriculture and the Environmental Protection Agency, Release No. 0345.00 (Sept. 29, 2000), available at <http://www.usda.gov/news/releases/2000/09/0345.htm> (citing that "[a]t the urging of the U.S. Department of Agriculture and the Environmental Protection Agency, Aventis will purchase this year's crop of StarLink corn . . . to prevent the current crop of StarLink corn from being used in processed foods").

¹³⁸ AVENTIS, AVENTIS CROPSOURCE STATUS REPORT ON STARLINK (Nov. 9, 2000), available at <http://www.aventis.com/main/page.asp?pageid=63336185872770551170&lang=en> (citing that "recalls of food companies have removed [products containing DNA from StarLink corn] from the food supply").

¹³⁹ See CDC REPORT, *supra* note 130. Blood tests failed to find signs of antibodies to the protein in the genetically engineered corn. Thus, the federal Centers for Disease Control and Prevention ("CDC") concluded that although the study participants may have experienced allergic reactions, based upon the results of their study alone, CDC "could not conclude that a reported illness was a [StarLink] allergic reaction." *Id.* CDC also cautioned that they could not rule out the possibility because food allergies may occur without detectable serum antibodies to the antigen. *Id.*

¹⁴⁰ Bratspies, *supra* note 127, at 628, 645.

¹⁴¹ NATIONAL CENTER FOR ENVIRONMENTAL HEALTH, CDC, INVESTIGATION FOR HUMAN HEALTH EFFECTS ASSOCIATED WITH POTENTIAL EXPOSURE TO GENETICALLY MODIFIED CORN, at <http://www.cdc.gov/nceh/ehhe/Cry9cReport/> (June 11, 2001); see also EPA, ADVISORY PANEL REPORT ASSESSES SCIENTIFIC INFORMATION CONCERNING STARLINK CORN, at <http://www.epa.gov/scipoly/sap/2000/november/starlinkpress.pdf> (Dec. 5, 2000).

¹⁴² The presence of StarLink corn in human food was unambiguously unlawful, rendering the foods in question adulterated under the Food, Drug, and Cosmetic Act, and violating the corn's Plant Incorporated Pesticide Registration. See *Bacillus Thuringiensis* subspecies *tolworthi* Cry9C Protein and the Genetic Material Necessary for its Production in Corn: Exemption From the Requirement of a Tolerance, 63 Fed. Reg. 28,258 (May 22, 1998). This exemption eliminated the need to establish a maximum permissible level for residues of this plant pesticide in, or on, corn used for feed, as well as in meat, poultry, milk, or eggs resulting from animals fed such feed. The exemption specifically did not permit human consumption of the StarLink corn itself.

¹⁴³ For a full exploration of the StarLink crisis, see Bratspies, *supra* note 127, at 594-98.

company to develop and commercialize a biopharmed product.¹⁴⁴ Among the advantages ProdiGene touts for its “plant delivery system” is a “comprehensive Compliance Plus System that demonstrates a strong commitment to proactive safety measures.”¹⁴⁵ Twice in 2002, this “Compliance Plus System” failed to ensure that the most basic preventative measures were observed at two ProdiGene test sites. Indeed, recently disclosed APHIS records reveal that before these incidents, Prodigene had already racked up a lengthy series of violations over an extended period of time, with few, if any, consequences.¹⁴⁶

ProdiGene’s 2002 violations again involved failures to implement legally required physical containment measures.¹⁴⁷ Both violations occurred in the Corn Belt—one in Nebraska and the other in Iowa.¹⁴⁸ At both sites, government inspectors discovered ProdiGene corn, which had been engineered to produce a swine vaccine, growing amidst soybeans destined for human consumption.¹⁴⁹ These plants were “volunteers” having grown from seeds left in the soil from a prior year’s field trial. Despite a warning to destroy the biopharm corn,¹⁵⁰ the Nebraska grower instead harvested his fields and sent the soybeans to an elevator where stalks and leaves from the bioengineered corn were commingled with the soybeans already present in the elevator.¹⁵¹ Because the soybeans were now contaminated with the non-food biopharm corn, APHIS ordered the destruction of all 500,000 bushels of soybeans in the elevator.¹⁵² In response to the Iowa violations, APHIS ordered Prodigene to uproot and destroy 155 acres of surrounding conventional corn because the biopharm corn was not adequately separated and, therefore, might have pollinated the food corn.¹⁵³

USDA levied a \$250,000 fine against Prodigene,¹⁵⁴ but the underlying problem remains. Clear and legally binding requirements for how this biopharm crop was to

¹⁴⁴ PRODIGENE, PLANT BIOTECHNOLOGY INTRO, at <http://www.prodigene.com/0201.htm> (Mar. 23, 2004).

¹⁴⁵ PRODIGENE, OUR TECHNOLOGY PLATFORM, at <http://www.prodigene.com/0202.htm> (Mar. 23, 2004).

¹⁴⁶ APHIS, USDA, BIOTECHNOLOGY REGULATORY SERVICES, WHAT IS THE COMPLIANCE HISTORY WITH APHIS BIOTECHNOLOGY REGULATIONS?, at <http://www.aphis.usda.gov/brs/compliance9.html> (Nov. 17, 2003).

¹⁴⁷ Press Release, APHIS, USDA, USDA Investigates Biotech Company for Possible Permit Violations (Nov. 13, 2002), at <http://www.aphis.usda.gov/lpa/news/2002/11/prodigene.html>.

¹⁴⁸ *Id.*

¹⁴⁹ Emily Gersema, *Agriculture Department Fines ProdiGene for Biotech Mishaps*, ASSOCIATED PRESS, Dec. 7, 2002, at <http://earthboundfarm.com/news-world/GMOfine.html>; CNN NEWS, FEDS PROBE BIOTECH FIRM FOR CROP MIXING, at <http://www.cnn.com/2002/US/11/14/biotech.contamination> (Nov. 14, 2002).

¹⁵⁰ Philip Brasher, *Biotech Corn May Have Tainted Soybeans*, DES MOINES REG., Nov. 13, 2002, at A1.

¹⁵¹ *Id.*; see also *Corn Near Gene-Altered Site to be Destroyed*, N.Y. TIMES, Nov. 14, 2002, at C10.

¹⁵² Brasher, *supra* note 150; *Corn Near Gene-Altered Site to be Destroyed*, *supra* note 151.

¹⁵³ Brasher, *supra* note 150; *Corn Near Gene-Altered Site to be Destroyed*, *supra* note 151; Press Release, APHIS, *supra* note 147.

¹⁵⁴ Press Release, USDA, USDA Announces Actions Regarding Plant Protection Act Violations Involving ProdiGene, Inc. (Dec. 6, 2002), available at <http://www.usda.gov/news/releases/2002/12/0498.htm>. ProdiGene was assessed a \$250,000 fine and required to pay more than \$3 million to repurchase the soybeans and to clean the silo. See CHRISTOPHER DOERING, PRODIGENE TO SPEND MILLIONS ON BIO-CORN TAINTING, at <http://www.planetark.org/avantgo/dailynewsstory.cfm?newsid=18935> (Sept. 12, 2002). USDA also required Prodigene to post a \$1 million bond and to comply with additional compliance standards, including additional approvals before field testing and harvesting genetically modified material. Press Release, USDA, *supra*. The company will be required

be handled were ignored.¹⁵⁵ The ProdiGene incidents illustrate the problems inherent to using food plants to produce non-food drugs or industrial feedstocks. Although the biopharm version looks just like the food crop, the two are not fungible.¹⁵⁶ In this case, none of the biopharmed corn seems to have made it all the way into the food supply, but it was a close call.

Unfortunately, StarLink and ProdiGene are not the only examples of how lax compliance with physical segregation requirements threatens the U.S. food supply. As 2002 drew to a close, EPA announced it had levied fines against two more biotechnology firms, this time in Hawaii, for failure to properly manage experimental, non-food GM crops.¹⁵⁷ Dow Agrosiences and Pioneer Hi-Bred were both fined for failure to take proper measures to prevent corn intended for human consumption from being contaminated with experimental, non-approved GM corn.¹⁵⁸ As part of the settlements, both companies reaffirmed their commitment to following permit conditions in the future and to immediately reporting any irregularities or violations.¹⁵⁹ Just four months later, however, Pioneer Hi-Bred was again in hot water. EPA fined the company \$72,000 for failing to notify EPA immediately of a new incident in which experimental, non-food corn contaminated food crops.¹⁶⁰

These incidents are only the most public face of a growing problem of contamination and commingling. In October of 2003, APHIS revealed for the first time that Monsanto and its partners violated federal regulations for planting biopharmed or otherwise unapproved GM crops forty-four times from 1990 to 2001 and paid \$69,550 in fines in four of those cases.¹⁶¹ In 2003, Monsanto also discovered that its Roundup Ready "Quest" canola seeds were contaminated with an unapproved transgene, necessitating the urgent recall of thousands of bags of canola seed during planting season.¹⁶²

The growing evidence of cross-contamination from biopharm and experimental GM crops raises serious questions about the overall likelihood that biopharming can

to develop a written compliance program designed to ensure future compliance with the Plant Protection Act, federal regulations, and permit conditions. *Id.*

¹⁵⁵ Brasher, *supra* note 150.

¹⁵⁶ For an explanation of the violations and their consequences, see TOM ZINNER, NEBRASKA CROP CONTAMINATION ISSUE BRIEFING, at <http://www.biotech.wisc.edu/Education/prodigene.html> (Nov. 14, 2002).

¹⁵⁷ Justin Gillis, *EPA Fines Biotechs for Corn Violations*, WASH. POST, Dec. 13, 2002, at E3 [hereinafter Gillis, *EPA Fines*]; Justin Gillis, *Corn Growing Far Afield? A Mishap with Gene-altered Grain Spotlights the Odds of Contamination*, WASH. POST, Nov. 16, 2002, at E1 [hereinafter Gillis, *Corn*]. Because the experimental GM corn involved in these incidents was engineered to produce a pesticide, the field test fell under EPA's FIFRA authority.

¹⁵⁸ Gillis, *Corn*, *supra* note 157. On a related note, FDA is investigating whether genetically modified pigs were improperly sold into the human food supply. Aaron Zitner, *Pigs in Genetic Study May Have Ended Up as Food*, L.A. TIMES, Feb. 6, 2003, at A17. This incident underscores the very real possibilities that any GM products might wind up in the human food supply. The likely effects of a failure to segregate must be considered at the approval stage.

¹⁵⁹ Gillis, *EPA Fines*, *supra* note 157; see also Stephen Tvedten, *Two Biotech Companies Fined for Violations*, at <http://safe2use.com/ca-ipm/02-12-18e.htm> (Dec. 16, 2002).

¹⁶⁰ Justin Gillis, *Firm Fined for Spread Of Altered Corn Genes: Government Wasn't Told Soon Enough*, WASH. POST, Apr. 24, 2003, at E4.

¹⁶¹ Randy Fabi, *USDA Reports 115 Infractions of Biotech Rules*, REUTERS, Oct. 20, 2003, available at <http://www.calgefree.org/news/sept2003.shtml>.

¹⁶² Judy Steed, *Seeds of Conflict*, TORONTO STAR, Nov. 12, 2003, available at <http://www.mindfully.org/GE/2003/Percy-Schmeiser-Monsanto12nov03.htm>. This discovery was reminiscent of Garth seed's discovery in 2000 that StarLink transgenes had contaminated other hybrid corn varieties.

be done safely in food crops.¹⁶³ This history of multiple lapses and failures to follow containment protocols do not bode well for safe use of this technology. That basic safety precautions were not taken during the earliest stages of the technology's development ought to raise alarms regarding what will happen if the crops ever go into full-scale production. Environmental and human health impacts of biopharming will only increase as more and more of these crops are planted. These concerns are magnified by proposals to produce more than one novel protein simultaneously in the same plant, and/or to reuse the crops as food once the biopharm compounds have been extracted, a proposal known as "co-production."¹⁶⁴

B. USDA HAS ABDICATED ITS REGULATORY RESPONSIBILITIES

The United States has no comprehensive statute addressing the testing and monitoring of genetically engineered products. Indeed, such products have never been tested for long-term effects on human health. Rather, genetically engineered products are regulated under existing statutes relating to food, drugs, agriculture, or the environment based on the product's intended use.¹⁶⁵ FDA,¹⁶⁶ USDA,¹⁶⁷ and EPA¹⁶⁸ all have partial authority over various aspects of GM crops. In theory, USDA determines whether a GM crop is safe to grow, FDA if it is safe to eat, and EPA if it is safe for the environment.¹⁶⁹

¹⁶³ See DANILA ODER, IS BIOPHARMING WORTH THE RISK?, at <http://www.inquisitoronline.com/news/0306gm.html> (June 1, 2003).

¹⁶⁴ See COMMITTEE ON BIOBASED INDUSTRIAL PRODUCTS, *supra* note 10, at 4 (emphasizing that such "co-production" could minimize conflicts with use of land for food production); Glynis Giddings et al., *Transgenic Plants as Factories for Biopharmaceuticals*, 18 NATURE BIOTECHNOLOGY 1151 (2000) (suggesting that the costs of purifying specialty chemicals could be defrayed by selling the food components of the crop).

¹⁶⁵ See Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. 23,302 (June 26, 1986).

¹⁶⁶ FDA regulates biotechnology products under statutes relating to food (except for meat, poultry, and egg products, which are regulated by the USDA), feed, drugs, and medical devices. See 21 U.S.C. §§ 301, 395 (2000); 21 C.F.R. §§ 171.1-571.1 (2003). In May 1992, FDA published a policy statement regarding food derived from new plant varieties. In this statement, FDA concluded that food and feed derived from genetically modified organisms should be regulated in the same manner as food and feed derived from traditionally bred plants, which leaves the responsibility of assuring the safety of the food with the producer. See Statement of Policy: Foods Derived from New Plant Varieties, 57 Fed. Reg. 22,984 (May 29, 1992).

¹⁶⁷ USDA regulates biotech crops under the PPA, 7 U.S.C. §§ 7701-7772 (2000), which consolidated several previous statutes that APHIS used to regulate genetically engineered organisms, including the Federal Plant Pest Act, 7 U.S.C. §§ 150aa-150jj, and the Plant Quarantine Act, 7 U.S.C. §§ 151-164a, 166-167. The Secretary of Agriculture has delegated her authority under the PPA to APHIS, and I will use APHIS and USDA interchangeably in this discussion. Because no new regulations have yet been issued pursuant to the PPA, APHIS continues to regulate biotechnology products according to the regulations issued under the old statutes. For USDA's Internet site on biotechnology, see <http://www.aphis.usda.gov/brs/index.html>.

¹⁶⁸ EPA regulates genetically modified organisms primarily under statutes relating to toxic substances and pesticides. See Toxic Substances Control Act ("TSCA"), 15 U.S.C. §§ 2601-2629 (2000) (regulating toxic substances); FIFRA, 7 U.S.C. §§ 136-136y (regulating pesticides). Under TSCA, EPA regulates GM microorganisms, and under FIFRA it regulates so-called plant incorporated protectants (like Bt crops) and pesticidal microorganisms. EPA also has responsibilities under the FFDCA, 21 U.S.C. §§ 346a(a)-(o) (regulating tolerances or exemptions for the requirement of a tolerance for pesticide residues in foods). Relevant regulations may be found at 40 C.F.R. § 152.1-.500, 2172.1-.59, 180.1-.1206, 725.1-.1000 (2003).

¹⁶⁹ APHIS, USDA, UNITED STATES REGULATORY OVERSIGHT IN BIOTECHNOLOGY: RESPONSIBLE AGENCIES—OVERVIEW, at <http://www.aphis.usda.gov/brs/usregs.html> (last visited June 26, 2004).

Biopharming does not fit well into this regulatory scheme. Although the therapeutics produced through biopharming will be drugs (and will thus be subject to FDA's traditional drug safety evaluations under the FFDCA), the crops themselves are neither drugs nor food. Thus, even though it is inevitable that these biopharm products will find their way into the food supply, the biopharm crops fall entirely outside FDA's scope of authority. Unless the biopharm crops also produce pesticides, EPA has no authority over these crops either, even though there are clear environmental risks from spread of biopharm pollens or proteins. Thus, it falls solely to USDA to regulate biopharming.

Under the best of circumstances, properly regulating these crops would be a daunting task. Circumstances are, however, far from ideal. USDA regulates these crops under the same authority it uses to regulate other GM crops—the Plant Protection Act (“PPA”).¹⁷⁰ The PPA focuses primarily on agronomic risks, and does not give USDA a clear mandate to consider food safety or environmental concerns.¹⁷¹ Not only is its regulatory authority constrained, but USDA has an added problem—it holds conflicting mandates both to protect safety and to promote this new industry.

In 2002, Secretary Veneman established the Biobased Products and Bioenergy Coordination Council (“BBCC”)¹⁷² to “facilitate and promote research, development, transfer of technology, commercialization, and marketing for biobased products and [B]ioenergy using renewable domestic agricultural (plant, animal and marine) and forestry materials.”¹⁷³ Among the identified goals of the BBCC is “establish[ing] USDA as the lead advocate for the development and commercialization of biobased industrial and commercial products.”¹⁷⁴ USDA, the lead regulatory agency, self-described itself as the technology's lead advocate and announced that it would “cooperate with the private sector in developing and demonstrating the potential commercial viability”¹⁷⁵ of biopharming. With the agency avowing its intent to encourage accelerated research and development,¹⁷⁶ who, if anyone, is protecting the public's interests in having this technology exploited only under conditions that protect human health and environmental safety?

This conflict between protection and promotion is visible in the regulatory scheme APHIS adopted. Until recently, scrutiny of biopharm crops was extremely light.¹⁷⁷ Field tests could proceed under a streamlined notification process and no permit was required.¹⁷⁸ On March 6, 2003, in response to the StarLink, ProdiGene, and Hawaii incidents, APHIS announced new requirements for biopharm crops to be

¹⁷⁰ PPA, 7 U.S.C. § 7701.

¹⁷¹ See Bratspies, *supra* note 127, at 602-03.

¹⁷² Agriculture Secretary Ann M. Veneman ordered the establishment of the Biobased Products and Bioenergy Coordination Council in 2002. USDA, DEPARTMENTAL REGULATION 9600-002, at <http://www.ars.usda.gov/Bbcc/DR9600-002.htm> (Aug. 26, 2002) [hereinafter USDA DEPARTMENTAL REGULATION].

¹⁷³ *Id.*

¹⁷⁴ USDA, STRATEGIC PLAN FOR BIOBASED PRODUCTS THROUGH THE BIOBASED PRODUCTS AND BIOENERGY COORDINATION COUNCIL, at http://www.ars.usda.gov/Bbcc/BBCC_strateg.htm (June 1999).

¹⁷⁵ USDA DEPARTMENTAL REGULATION, *supra* note 172.

¹⁷⁶ *Id.*

¹⁷⁷ For a discussion of the flawed regulation of genetically modified crops, see Bratspies, *supra* note 127.

¹⁷⁸ See *id.* at 604-05.

implemented for the 2003 growing season and beyond.¹⁷⁹ In its summary of the new rules, APHIS emphasized that these biopharm products are never meant to enter the food supply and indicated that a stringent regulatory system would be necessary.¹⁸⁰ To that end, APHIS imposed safety measures based on plans for physical segregation. Seeking to control the likely routes for contamination, the new requirements introduced regular inspections, and imposed growing conditions and farm equipment standards.¹⁸¹ For the first time, there were: 1) mandatory field site inspections;¹⁸² 2) a requirement that no biopharm corn be grown within one mile of open-pollinated corn;¹⁸³ and 3) restrictions on the production of food and feed crops at the field test site and perimeter fallow zone in the subsequent growing season.¹⁸⁴ In addition to these in-field physical containment measures, APHIS also imposed a series of logistical requirements designed to minimize contact. APHIS required that biopharm crops be planted and harvested with dedicated mechanized equipment that will be stored in dedicated facilities.¹⁸⁵ In addition, APHIS must approve equipment cleaning procedures¹⁸⁶ and seed cleaning and drying procedures,¹⁸⁷ and all biopharm producers must attend a training program to increase the likelihood of compliance with permit conditions.¹⁸⁸

APHIS characterized these new regulations as a revision of the regulatory framework “that reflects the latest science and information so that we can maintain the integrity of our systems.”¹⁸⁹ Although APHIS claimed that the new conditions were “science based and reflect[ed] the anticipated increase of requests for permits for plants genetically engineered to produce pharmaceutical and industrial compounds,”¹⁹⁰ it is clear that this agency action was reactive rather than proactive. For example, until the 2003 growing season there were still no analogous (or for that matter any) requirements for industrial biopharm crop permits.¹⁹¹ On August 6, 2003, a full decade after the first field tests of industrial biopharm crops,¹⁹² APHIS finally published an interim rule requiring that industrial biopharm crops be field

¹⁷⁹ Field Testing of Plants Engineered to Produce Pharmaceutical and Industrial Compounds, 68 Fed. Reg. 11,337 (Mar. 10, 2003). For a commentary on this APHIS response to the misuse of genetically engineered crops, see KARIL KOCHENDERFER, COMMENTS SUBMITTED RE: DOCKET NO. 03-031-1, at <http://www.gmabrands.com/publicpolicy/docs/comment.cfm?DocID=1135> (last visited June 26, 2004).

¹⁸⁰ APHIS, USDA, HIGHLIGHTS OF THE FEDERAL REGISTER NOTICE: CHANGES IN THE PERMIT CONDITIONS FOR 2003, at <http://www.usda.gov/news/releases/2003/03/aphisfactsheet030603.pdf> (last visited Apr. 7, 2004).

¹⁸¹ 68 Fed. Reg. at 11,337.

¹⁸² *Id.* at 11,338-39. Under the new regulations, every test site will be inspected during critical times in the biopharm production cycle. Up to five site visits might be made during the growing season, with another two for assessing volunteer plants the following year. Under the old rules, plots were rarely inspected.

¹⁸³ *Id.* at 11,338.

¹⁸⁴ *Id.*

¹⁸⁵ *Id.*

¹⁸⁶ *Id.*

¹⁸⁷ *Id.*

¹⁸⁸ *Id.*

¹⁸⁹ Press Release, APHIS, USDA, USDA Strengthens 2003 Permit Conditions for Field Testing Genetically Engineered Plants (Mar. 6, 2003), available at <http://www.usda.gov/news/releases/2003/03/aphis030603.htm> (statement of Bobby Acord, APHIS Administrator).

¹⁹⁰ *Id.*

¹⁹¹ Introductions of Plants Genetically Engineered to Produce Industrial Compounds, 68 Fed. Reg. 46,434 (Aug. 6, 2003).

¹⁹² *Id.*

tested, moved, or imported only with a duly issued permit.¹⁹³ The interim rule will be in effect until December 2004.¹⁹⁴ Prior to 2003, field testing could be conducted under the expedited notification provisions, with no set standards for containment or oversight.¹⁹⁵ Between 1993 and 2001, APHIS received ten notifications of introduction of plant-made industrials.¹⁹⁶ In the first half of 2003 alone, APHIS received five permit applications.¹⁹⁷ Only public disclosure of the ProdiGene near-miss, coming on the heels of the StarLink fiasco prompted APHIS to act.

It remains to be seen how APHIS will administer its physical containment measures. As the crops move into commercial production, it is extremely unlikely that APHIS will be able to oversee or enforce these regulations. APHIS reports that in 2002, 130 acres of pharmaceutical biopharm crops were planted at thirty-four sites, most of which were smaller than 5 acres.¹⁹⁸ Thus, using 2002 as an example, APHIS new regulations would have required a minimum of 238 site visits (seven per site: five during the growing season and two thereafter).¹⁹⁹ That number does not include any industrial sites.²⁰⁰ In 2000 and 2001, APHIS had ten staff members to evaluate biotech applications.²⁰¹ Even before APHIS adopted this stepped up inspection regime, the National Research Council concluded that APHIS did not employ enough personnel to visit all the field test sites and that many of the inspectors were poorly trained.²⁰² In years when there is an emergency priority, such as the recent European foot and mouth disease outbreak, even fewer inspectors are available to inspect biopharm field tests.²⁰³

While APHIS might theoretically retain sufficient staff and resources to conduct 238 visits to the existing field trials (the National Research Council concluded that ten APHIS employees' duties included inspecting these fields),²⁰⁴ the agency has indicated that it expects requests for field test permits and the scale of production to increase significantly over the next few years.²⁰⁵ APHIS' overloaded staff already reviews approximately 1,000 applications for field testing and deregulation of transgenic plants each year.²⁰⁶ It is hard to imagine agency resources stretching

¹⁹³ *Id.*

¹⁹⁴ *Id.* at 46,435.

¹⁹⁵ *Id.* at 46,434.

¹⁹⁶ *Id.* at 46,435.

¹⁹⁷ *Id.* In March of 2003, APHIS published proposed rules for field testing plant-made pharmaceuticals and industrial chemicals. See *Field Testing of Plants Engineered to Produce Pharmaceutical and Industrial Compounds*, 68 Fed. Reg. 11,337 (Mar. 10, 2003). These proposed rules indicated that APHIS was considering extending permit requirements to plant-made industrials. *Id.* at 11,338. In a press release that accompanied publication of the proposed rules, APHIS indicated that the agency intended to publish an interim final rule that will require a permit for the field testing of industrials for the 2003 growing season, and strongly encouraged any 2003 applicants to request a permit for field testing industrials. Press Release, APHIS, USDA, USDA To Require Permits for All Industrial Biotech Plants (Aug. 5, 2003), available at http://www.aphis.usda.gov/brs/industrial_biotech.html. Accordingly, those entities submitting proposals in 2003 submitted permit applications rather than notifications. See 68 Fed. Reg. at 46,435.

¹⁹⁸ *Id.*

¹⁹⁹ *Id.*

²⁰⁰ *Id.*

²⁰¹ ENVIRONMENTAL EFFECTS, *supra* note 14 at 182.

²⁰² *Id.*

²⁰³ *Id.*

²⁰⁴ *Id.*

²⁰⁵ See *Field Testing of Plants Engineered to Produce Pharmaceutical and Industrial Compounds*, 68 Fed. Reg. 11,337 (Mar. 10, 2003).

²⁰⁶ ENVIRONMENTAL EFFECTS, *supra* note 14 at 1.

further. Certainly if the United States achieves the Roadmap vision of biopharming producing 10% of chemical feedstocks by 2020 (and that figure does not include the expected boom in biopharmaceuticals!), APHIS will not be able to conduct all the required visits. Indeed, the number of test plantings will not have to increase by much before APHIS' resources will be inadequate to make the promised seven visits over two years to each test plot. Moreover, once full production begins, the agency will not have the capacity to visit every commercial grower on such a schedule.

Without this critical piece of the regulatory patchwork, it is unclear how APHIS envisions fulfilling its compliance monitoring obligations, particularly since GM purveyors routinely use CBI claims to keep field test locations secret.²⁰⁷ Coupled with the lack of oversight staff, this prevalence of CBI claims is particularly troubling. While the companies have a legitimate interest in preventing corporate vandalism or corporate espionage, the public has a strong interest in knowing whether biopharmed crops are contaminating adjacent conventional crops with substances that are clearly not intended for human or animal consumption. Secrecy eliminates the possibility that private actors will be able to independently monitor contamination levels. Since there is no governmental monitoring system, and no requirement that the GM purveyors monitor surrounding fields for contamination, shutting off the possibility of third-party monitoring means that there will be no monitoring of any kind. Remember, the StarLink fiasco came to light solely as a result of vigilant third-party monitoring.²⁰⁸ The lack of independent monitoring is a serious deficiency, one that all but ensures that the regulatory scheme is unlikely to be responsive and trustworthy.

Indeed, these exact same constraints have prevented physical containment measures from achieving more than marginal success as a risk management tool for other GM crops, in particular those crops modified to express Bt toxins. Because of concerns about rapid evolution of pest resistance, EPA has developed some simple conditions for how Bt crops can be planted. In particular, EPA requires that, at most, 80% of the corn on a farm be Bt corn, with the other 20% conventional corn.²⁰⁹ In addition, these conventional corn refuges must be planted within one quarter mile of the Bt fields.²¹⁰ An industry survey conducted during the 2002 growing season indicated that 11% of farmers failed to comply with these requirements.²¹¹ The Center for Science in the Public Interest examined a parallel set of data submitted to USDA's National Agricultural Statistical Service, and discovered that growers self-reported information amounted to non-compliance levels 40% higher than those reported through the industry survey.²¹² Similarly, a USDA review of compliance found that 20% of Bt corn growers failed to comply

²⁰⁷ *Id.* at 11.

²⁰⁸ THE CAMPAIGN TO LABEL GENETICALLY ENGINEERED FOODS, GE FOODS TUTORIAL: STARLINK FIASCO INCREASES PRESSURE FOR REGULATION, at http://www.thecampaign.org/education/brochure_starlink.htm (last visited May 6, 2004).

²⁰⁹ See EPA, BIOPESTICIDES REGISTRATION ACTION DOCUMENT: BACILLUS THURINGIENSIS PLANT-INCORPORATED PROTECTANTS, at II.B.5, at http://www.epa.gov/pesticides/biopesticides/pips/bt_brad.htm (Oct. 16, 2001).

²¹⁰ *Id.*

²¹¹ AGRICULTURAL BIOTECHNOLOGY STEWARDSHIP TECHNICAL COMMITTEE, INSECT RESISTANCE MANAGEMENT GROWER SURVEY FOR 2002 BT FIELD CORN GROWING SEASON, at <http://www.ncga.com/index.shtml> (Dec. 19, 2002).

²¹² GREGORY JAFFE, PLANTING TROUBLE: ARE FARMERS SQUANDERING BT CORN TECHNOLOGY?, at http://cspinet.org/new/pdf/bt_corn_report.pdf (June 19, 2003).

with federal growing requirements.²¹³ The Prodigene fiasco certainly suggests that there is no reason to expect that biopharm growers will be any more compliant than are farmers growing other GM crops, and thus, depending on farmers to implement physical containment measures should not be the primary plan for keeping biopharm crops out of the food supply.

Even putting aside the careless or intentional acts at the root of StarLink (and Prodigene), the physical containment of living plants is next to impossible. Plants reseed themselves. It requires eternal vigilance on the part of the grower to eradicate the volunteer plants that grow the next season, and such vigilance is both time-consuming and expensive. Moreover, these volunteer plants might grow in neighboring fields in addition to the test fields themselves. Behaviors needed to control volunteer plants are not easily captured by a regulatory system based on physical segregation. The constant monitoring needed to identify and eradicate these volunteer plants places a significant burden on growers.

Because the risks are difficult to understand, and there is no way to recapture the added costs of this monitoring, growers are likely to slip up on their efforts. Any such lapses render physical containment measures—USDA's sole regulatory plan for protecting the food supply—wholly ineffective. These lapses are particularly likely because pollen drift is nearly impossible to control and is difficult to trace.²¹⁴ This is a fatal flaw in USDA's decision to rely exclusively on physical containment measures, and it is not amenable to easy solution. For physical containment to have any hope of working, growers must be committed and dedicated to eradicating volunteers. Nevertheless, USDA requires no certification or special training for biopharmers, nor has USDA created a monitoring and reporting system to track the occurrence of volunteer plants. In fact, USDA has no way to monitor either grower vigilance or actual incidents of contamination. Even if USDA required that growers report their planting patterns and actually followed up to ensure that the plantings correctly matched the submitted patterns, such measures would bear no relationship to grower vigilance against volunteers and would utterly fail to detect contamination of nearby fields.

Compounding the problem, USDA has not required biopharm companies to develop tests to identify biopharm contamination, nor has it developed such tests on its own.²¹⁵ Remember, biopharm crops are phenotypically indistinguishable from food crops. Without a readily available and easily performed identity test, grain silos and food manufacturers have no way to know whether they are inadvertently purchasing biopharmed crops. We have seen this before. It was precisely this inability to distinguish food corn from non-food corn that gave rise to the StarLink fiasco.²¹⁶ Successful risk management based on physical containment requires, at the very least, that contamination be readily identifiable.

²¹³ Emily Gersema, *USDA Survey Shows Biotech Rules Breaches*, TALLAHASSEE DEMOCRAT, Sept. 10, 2003, available at <http://www.tallahassee.com/mld/tallahassee/news/politics/6739974.htm>.

²¹⁴ See AMERICAN ASSOCIATION OF INSURANCE SERVICES, BREAKING NEW GROUND: HARMFUL OR NOT, GENETICALLY ENGINEERED FOOD COULD LEAD TO KNOTTY PROBLEMS, at <http://www.aaisonline.com/Viewpoint/01fall2.html> (last visited June 26, 2004).

²¹⁵ Aventis had not developed any such tests for StarLink corn prior to the StarLink fiasco. One recommendation made in the aftermath of that incident was that the government ensure that such tests are developed prior to the release of any genetically engineered crop. See ASSESSMENT OF ADDITIONAL SCIENTIFIC INFORMATION CONCERNING STARLINK CORN, FIFRA SCIENTIFIC ADVISORY PANEL, SAP REPORT NO. 2001-09, 39, at <http://www.epa.gov/scipoly/sap/2001/july/julyfinal.pdf> (July 17, 2001).

²¹⁶ Bratspies, *supra* note 127, at 624-25, 630.

In the most recent guidance to industry, USDA and FDA “strongly recommend,” but do not require, that companies develop tests to identify contamination in raw agricultural products.²¹⁷ A mere recommendation, however strong, is totally inappropriate here. Tests to discover contamination cannot be optional. In the absence of an express requirement, no biopharm developer has produced such a test. Without the test, there is no way to identify biopharm crops or contaminated crops and to ensure that such crops are diverted to non-food uses. Moreover, USDA’s guidance does not suggest, “strongly” or otherwise, that biopharm purveyors monitor adjacent crops for evidence of contamination. Apparently, APHIS has satisfied itself that its proposed field practices will prevent contamination. APHIS inspectors will, at best, monitor to see if those field practices are being met.²¹⁸ The agency has no intentions of monitoring, or requiring the biopharm purveyor to monitor, for actual contamination of nearby crops with non-food biopharm compounds.²¹⁹ Thus, there is no way to learn whether the physical containment practices, APHIS’ primary regulatory strategy, are working. The National Research Council points to this “lack of rigor” in APHIS procedures as a potential source of serious contamination problems.²²⁰ Indeed, in other contexts, FDA recognizes “develop[ing], enhanc[ing], and maintain[ing] surveillance systems that can quickly and accurately identify food safety risks in the human food” as the key to an effective emergency response capability.²²¹ Because USDA does not require that tests be developed to identify contamination, there is no such surveillance system for biopharmed crops and no way to respond quickly in an emergency. In light of the industry’s checkered history of contamination and commingling, there is no excuse for failing to require such tests.

IV. REPAIRING THE INADEQUATE AND POROUS REGULATORY SYSTEM

Non-food biotech products will enter the human food supply. After examining the prospect of corn biopharming in the Corn Belt, the National Research Council concluded that using food crops to produce non-edible and potentially harmful compounds creates serious regulatory issues.²²² In an unusually frank editorial, NATURE BIOTECHNOLOGY identified some of the major flaws with reliance on physical confinement: that gene-containment is next to impossible in the field and

²¹⁷ See FDA, GUIDANCE FOR INDUSTRY: DRUGS, BIOLOGICS, AND MEDICAL DEVICES DERIVED FROM BIOENGINEERED PLANTS FOR USE IN HUMANS AND ANIMALS, 67 Fed. Reg. 57828 (Sept. 12, 2002).

²¹⁸ Fields used to grow biopharm plants are subject to USDA inspection under 7 C.F.R. § 340.

²¹⁹ *Id.*

²²⁰ ENVIRONMENTAL EFFECTS, *supra* note 14, at 181. This NRC comment referred to field testing under notification. On August 6, 2003, APHIS issued an interim rule requiring that plants genetically modified to produce industrial compounds be field-tested only under a more rigorous permit system. Introductions of Plants Genetically Engineered to Produce Industrial Compounds, Interim Rule, 68 Fed. Reg. 46,434 (Aug. 6, 2003). For the 2003 growing season, APHIS had similarly decided that plants engineered to produce pharmaceutical compounds should be administered under permit rather than notification. See 7 C.F.R. § 340.3(b)(4)(iii) (2003). APHIS’ identified rationale for this shift was its lack of regulatory experience or scientific familiarity with the non-food, non-feed nature of biopharming. 68 Fed. Reg. 46,435.

²²¹ USDA, STATEMENT OF BERNARD A. SCHWETZ, ACTING PRINCIPAL DEPUTY COMMISSIONER, FDA, BEFORE THE SENATE GOV’T AFFAIRS SUBCOMM. ON OVERSIGHT OF GOV’T MGMT., RESTRUCTURING, AND THE DIST. OF COLUMBIA, at <http://www.fda.gov/ola/2001/foodsafety1010.html> (Oct. 10, 2001).

²²² ENVIRONMENTAL EFFECTS, *supra* note 14, at 229.

that farmers have proven to be unwilling or unable to follow planting rules.²²³ USDA's regulatory scheme takes neither of these critical variables into account.

In the 1970s, scientists responded to growing concerns that biotechnology was developing more rapidly than the ability to understand or manage the risks it posed by developing the Asilomar self-regulation plan.²²⁴ This plan was based on the conviction that standards of care should be "greater at the beginning and modified as improvements in the methodology occur and assessments of the risks change."²²⁵ Those lessons have powerful resonance today in the context of biopharming. In much the same way the Asilomar Conference imposed a moratorium to permit the development of more information about risk,²²⁶ there should be a moratorium on field testing biopharm crops to permit information about risks to catch up to the biopharming industry's technical capabilities to convert plants into biofactories. If industry cannot, or will not, self-impose these sensible restrictions,²²⁷ government must stand ready to take up the slack. Indeed, given the stakes, the government ought not rely on industry self-regulation as its first line of defense. Instead, taking a lead from the Asilomar Conference, APHIS should impose a temporary partial moratorium on biopharming. During this moratorium, which would be an interim period during which research on the health effects of these crops could be performed, the agency should restrict the technology to greenhouse plantings or to non-food crops. Such a decision would permit the technology to go forward, albeit more slowly, and with full respect for the many unknowns. Once more scientific information has been gathered, the agency and the public can make informed choices about the risks and benefits associated with biopharming.

A. POSSIBLE FDA REGULATORY MEASURES

A strong base of scientific knowledge is the foundation of any successful food safety system.²²⁸ FDA claims that food safety must rest on strong "risk-based prevention standards" to prevent contamination of all human foods and animal feeds over "the farm-to-table continuum."²²⁹ The risks here are plain and this same rigor must be brought to biopharm crops. Even in the face of USDA reluctance to involve FDA in approving biopharm crops, the agency need not be entirely passive. FDA could influence industry behavior by declaring "biopharm action levels"—the conditions under which the agency might seek to have a court find a food adulterated by biopharm crops.²³⁰ By publicly announcing its enforcement policy, FDA might spur industry to confront these questions and thus drive development of this technology towards safer options.²³¹ There is no justification for failing to use the

²²³ *Going with the Flow*, 20 NATURE BIOTECHNOLOGY 527 (2002).

²²⁴ Berg et al., *Asilomar Conference*, *supra* note 45.

²²⁵ *See id.*

²²⁶ *Id.*

²²⁷ One critical difference between biopharm research at the time of the Asilomar Conference and research today is that most biopharm research is industry funded, and thus subject to commercial pressures from investors that Asilomar scientists did not have to face.

²²⁸ INSTITUTE OF MEDICINE, ENSURING SAFE FOOD FROM PRODUCTION TO CONSUMPTION 91-93 (1998), available at <http://books.nap.edu/books/0309065593/html/index.html>.

²²⁹ *Id.*

²³⁰ *See* 21 U.S.C. §§ 331, 332, 342(a)(1) (2000); 21 C.F.R. §§ 109.4, 109.6 (2003).

²³¹ *Cf.* Daniel A. Farber, *Taking Slippage Seriously: Noncompliance and Creative Compliance in Environmental Law*, 23 HARV. ENVTL. L. REV. 297, 307-09 (1999) (describing creative enforcement in the context of the Endangered Species Act).

full arsenal of agency powers to respond to this serious threat to the safety of the food supply.

Given what we know from experience with other GM crops, it is entirely inappropriate for the government to approach biopharming on a post hoc basis. Regulators must be involved at the planning stages; they cannot wait for developers come to the agencies with a largely completed product. At that point, modifications to protect public health are after-the-fact add-ons, and are far more expensive and less effective than design modifications would have been during the development process.

B. POSSIBLE BIOLOGICAL CONTROL MEASURES

In the earliest stages of biotechnology, the Asilomar Conference recognized that “[t]he most significant contribution to limiting the spread of recombinant DNA is the use of biological barriers.”²³² Somehow this initial insight was lost. Rather than a mere “additional factor of safety,”²³³ physical containment measures have taken precedence as the primary means to contain biopharming’s adverse effects. This inverted reliance on physical, rather than biological, containment measures must be reversed.

1. Use of Non-Food Crops

APHIS’ post-Prodigene physical containment requirements mark a start towards responsible regulation. The requirements will undoubtedly strengthen the protections of the food supply, but they are too little, too late. Other measures would provide far greater protection without simultaneously creating the need for a detailed and expensive oversight system.

The most obvious of these measures would be to require that biopharming occur only in non-food crops like tobacco, hemp or switch grass. Simply put, since it will not be possible to keep biopharm corn out of the food supply, food crops should not be production vehicles for biopharming.²³⁴ Such a rule would be the clearest way to protect public health while still permitting society to benefit from the potential represented by this new technology. In one fell swoop, USDA could eliminate any possibility of commingling. The clean regulatory line of “no biopharming in food crops” would be easy to comply with, thus fitting neatly into the various vision statements and roadmaps aimed at nurturing this technology by avoiding burdensome regulation. Moreover, many biopharm developers have hedged their bets and have proceeded with parallel development of biopharm crops in tobacco.²³⁵

²³² Berg et al., *Summary Statement*, *supra* note 46, at 1982.

²³³ *Id.*

²³⁴ In addition to contamination of the food supply, biopharming also raises questions about the environmental effects of gene flow to wild relatives. “Twelve of the world’s thirteen most important crops are known to hybridize with wild relatives somewhere in their agricultural range.” Ralph Haygood et al., *Consequences of Recurrent Gene Flow from Crops to Wild Relatives*, 270 PROC. R. SOC. LOND. B. 1879, 1879 (2003). Indeed, of the top sixty crop plants, only eleven do not hybridize with wild relatives somewhere in the world, and a majority has wild relatives in the United States. Daniell, *supra* note 8, at 361. These questions would not be resolved by restricting biopharming to non-food crops, though, because it would reduce the likelihood of contaminated pollen, chloroplast transformation would certainly reduce the environmental impacts these crops will have on natural ecosystems.

²³⁵ See Margot Roosevelt, *Cures on the Cob*, TIME, May 26, 2003, at 56; see also Jonathan Nevit et al., *Participatory Assessment of the Social and Economic Impacts of Biotechnology* (2003)

Thus, non-food biopharming could serve a dual public interest—providing access to needed therapeutics while, at the same time, weaning tobacco farmers from a perverse dependence on a continued market for cigarettes.

The biopharming industry itself agrees that it cannot afford another public relations disaster, and certainly not a public health catastrophe.²³⁶ Food producers have called for a ban on biopharming in food crops.²³⁷ The Grocery Manufacturers of America have also urged biotech companies to stop using food crops as vehicles for growing biotech products that humans and animals are not supposed to eat.²³⁸

2. Chloroplast Transformation

At the very least, biopharm crops should always be modified through chloroplast transformation²³⁹—a means to produce high levels of novel proteins while ensuring that the pollen does not contain transgenes.²⁴⁰ Because chloroplasts are maternally inherited, there are usually no chloroplasts in pollen.²⁴¹ Transforming chloroplast DNA rather than nuclear DNA would greatly reduce the threat of cross-pollination.²⁴² As such, this biological containment mechanism could be a partial solution to contamination of the food supply. Ideally, those two biological safety measures would be combined so that biopharming occurs in non-food crops that have undergone chloroplast transformation. These biological segregation methods could be added to the physical segregation methods APHIS now imposes, but the need for oversight would be less pressing because the risks to human health would be radically reduced. Although biopharm crops are developed enough to make these design modification choices expensive, and therefore unpalatable, it is not too late to require these sensible and practical restrictions on exploitation of the new technology.

(unpublished working paper, Virginia Tech), at <http://www.agecon.vt.edu/biotechimpact/tobacco/WP20031.pdf>.

²³⁶ See Justin Gillis, *Biotech Industry Adopts Precaution: Altered Plants Banned Near Major Food Crops*, WASH. POST, Oct. 22, 2002, at E1, E4 (quoting Michael H. Pauley executive director of biotechnology for Epicyte Pharmaceutical Inc., which is testing a herpes drug grown in corn as saying “I think we can all agree that this industry cannot afford StarLink II. . . . One incident like that is unacceptable. It’s going to require a certain standard of behavior from the entire industry.”).

²³⁷ Philip Brasher, *Biotech Firm Under Fire Has Links to Iowa*, DES MOINES REG., Nov. 14, 2002, available at <http://desmoinesregister.com/business/stories/c4789013/19735220.html>.

²³⁸ Press Release, Grocery Manufacturers of America, GMA Urges the Use of Non-Food Crops for Biotech Drugs (Nov. 14, 2002), available at <http://www.gmabrands.com/news/docs/NewsRelease.cfm?DocID=10298>.

²³⁹ Simon Geir Moller et al., *The Topological Specificity Factor AtMinE1 Is Essential for Correct Plastid Division Site Placement in Arabidopsis*, 31 PLANT J. 269 (2002).

²⁴⁰ Henry Daniell, *GM Crops: Public Perceptions and Scientific Solutions*, 4 TRENDS IN PLANT SCI. 467, 468 (1999); Henry Daniell et al., *Containment of Herbicide Resistance Through Genetic Engineering of the Chloroplast Genome*, 16 NATURE BIOTECHNOLOGY 345 (1998); Susan E. Scott & Mike J. Wilkinson, *Low Probability of Chloroplast Movement from Oilseed Rape (Brassica napus) Into Wild Brassica rapa*, 17 NATURE BIOTECHNOLOGY 390 (1999).

²⁴¹ S. Milius, *The Green Genes Don't Get Out Much*, SCIENCE NEWS, April 10, 1999, available at http://www.findarticles.com/cf_dls/ml200/15_155/54492437/pl/article.jhtml.

²⁴² Some researchers believe that, because of their prokaryotic nature, chloroplasts are ideal for biopharming therapeutics that are currently produced in *E.coli* systems, including vaccines and antibodies. See Daniell, *supra* note 8, at 366.

3. Other Available Containment Measures

Making the biopharm crops “look different” would be another common sense precaution that would greatly reduce the risk to the food supply. More than a decade ago, researchers successfully engineered firefly luciferase²⁴³ and green fluorescent protein into tobacco, rendering the crop luminescent.²⁴⁴ Other phenotypic markers like restricting biopharming to purple maize varieties and banning the use of these varieties in food could also make tracking biopharm crops a more straightforward proposition and contamination more readily identifiable.

Another layer of protection could be added through geographic containment: banning the planting of biopharm crops where their conventional counterparts are grown for food, and requiring extensive food safety testing before permitting field testing of any biopharm crop that is also used for food. Because this new technology will potentially be very lucrative,²⁴⁵ such calls face stiff political opposition from Corn Belt officials who do not want their states left out.²⁴⁶ Indeed, in the wake of the ProdiGene incident, Biotechnology Industry Organization (“BIO”), a biotech industry trade group, issued a commitment not to grow biopharm corn in the Corn Belt.²⁴⁷ Reaction from Corn Belt politicians was immediate and negative.²⁴⁸ BIO quickly backed down.²⁴⁹ Only the federal government has the power to make such a rule stick, and the resources to provide enough of a countervailing benefit to make the rule palatable.

Any or all of these additional control measures would better protect the food supply than do USDA’s physical containment measures. Moreover, these measures would ensure that commercialization of biopharm crops is channeled only into paths that are likely to protect public safety. It is inexcusable that USDA has adopted none of these proactive measures but instead waits until biopharm crops are ready for field testing and then contents itself with imposing physical containment measures.

²⁴³ See, e.g., M. Schneider et al., *The In Vivo Pattern of Firefly Luciferase Expression in Transgenic Plants*, 14 PLANT MOL. BIOL. 935 (1990); Stephen J. Howell, *Transient and Stable Expression of the Firefly Luciferase Gene in Plant Cells and Transgenic Plants*, 234 SCIENCE 856 (1986).

²⁴⁴ Brian K. Harper et al., *Green Fluorescent Protein As A Marker for Expression of A Second Gene in Transgenic Plants*, 17 NATURE BIOTECHNOLOGY 1125 (1999); Staci Leffel et al., *Tracking Transgenic Plants Using Green Fluorescent Protein*, at <http://www.isb.vt.edu/brarg/brasym96/leffel96.htm> (last visited June 26, 2004). The most famous use of this marker is the well-known photo of a “glow-in-the-dark” rabbit.

²⁴⁵ Some industry estimates are that biopharmaceutical production may be a \$12-14 billion industry by 2005. See *Iowa State Response to the BIO Guidance Concerning “Plants Intended Not to Be Used for Food or Feed”*, at <http://www.grassley.senate.gov/releases/2002/p02r11-04a.htm> (last visited May 6, 2004) (objecting to BIO’s moratorium on the ground that it would exclude Iowa from lucrative biopharming opportunities).

²⁴⁶ See, e.g., Philip Brasher, *Iowa Denied New ‘Drug’ Corn*, DES MOINES REG., Oct. 23, 2002, at A1.

²⁴⁷ *Voluntary moratorium on planting some biotech crops in certain regions*, FOOD INSTITUTE REP., Oct. 28, 2002; Justin Gillis, *Biotech Industry Adopts Precaution: Altered Plants Banned Near Major Food Crops*, Wash. Post, Oct. 22, 2002 at E.1, E.4.

²⁴⁸ Iowa’s Senator Chuck Grassley led the campaign to get this commitment revoked stating: “BIO is responding to the demands of special interest, not the demands of science. I’ll continue to work to ensure that Iowa is not unjustly left out of corn-based pharmaceutical crop production.” Press Release, Grassley Continues Efforts to Support Biotech Crop Production in Iowa (Nov. 4, 2002), available at <http://www.grassley.senate.gov/releases/2002/p02r11-04.htm>.

²⁴⁹ Philip Brasher, *Biotech Group Lifts Corn Ban*, DES MOINES REG., Dec. 4, 2002, at A1.

When protection of the food supply rests entirely on physical containment measures, there are at least four likely routes for these biopharmed non-food crops to enter the human food supply: 1) direct human action intentionally or negligently contaminating the food supply; 2) volunteer plants contaminating the next year's food crops; 3) pollen drift contaminating nearby food crops; and 4) improperly cleaned farm machinery or spilled seeds contaminating food crops. All four have already occurred with experimental GM or biopharm crops, and unless steps are taken, all surely will occur again.

Under the Plant Protection Act, USDA has responded piecemeal to well-developed proposals upon which companies have already spent a great deal of money. Under such circumstances, and constrained by its tenuous lines of authority, USDA has not sufficiently considered overarching concerns. This regulatory hole is undeniably attributable to the agency's hopelessly conflicted mission, but is made worse by the absence of any laws directed specifically at regulating biotechnology.

The Framework's requirement that biotechnology be regulated under existing law seriously hampers agency ability to propose and enforce needed rules. Regulators have tried to cobble together a scheme by taking bits and pieces of a whole series of laws drafted to confront other problems. In doing so, they have already stretched existing laws almost beyond recognition,²⁵⁰ and all for naught. The regulatory scheme created by these contortions is simply not up to the task.

The status quo is unsafe and unacceptable. We must not wait for a tragedy before taking the sensible steps that will ensure safe exploration of this technology. We need laws and regulations that are directly on point. These laws must clarify the government's authority to supervise earlier stages in the biopharm crop development process in order to require biological containment measures. At least as important, specific agencies need express delegations of clear regulatory responsibilities and goals.²⁵¹ USDA has used tenuous lines of authority to make important and highly politicized policy decisions about a technology on the frontiers of science. It has made these decisions, moreover, with little or no scientific information, and in a political climate strongly favoring technology. It is perhaps not surprising that, under the circumstances, the agency has been wholly responsive rather than proactive.

Without direct congressional action on this front, we can expect only more of the same—the agency will continue to make post hoc approval decisions that do not, and indeed cannot, incorporate some of the most serious concerns about this new technology. The only way out of this conundrum is for Congress to take charge and

²⁵⁰ For example, FDA has expressed its intent to regulate transgenic salmon as an animal drug under the FFDCA. Aside from the problem that this claim of regulatory authority contorts the statutory language past all reasonable limits, this interpretation leaves gaping regulatory holes. For example, it is unclear whether FDA has authority to consider ecosystem harms. See PEW INITIATIVE ON FOOD AND BIOTECHNOLOGY, *FUTURE FISH: ISSUES IN SCIENCE AND REGULATION OF TRANSGENIC FISH* (2003), available at <http://pewagbiotech.org/research/fish/> (examining the ambiguity surrounding FDA's authority to consider environmental risks imposed by transgenic fish).

²⁵¹ For different perspectives on the measures necessary to cure these regulatory ills, see Marcia Ellen DeGeer, *Comment: Can Roundup Ready TM Seeds Ever Be Corralled?: Restraining Genetic Drift Through Criminal Sanctions*, 29 NEW ENG. J. CRIM. & CIV. CONFINEMENT 255 (2003) (arguing for use of criminal penalties to deter genetic drift); Thomas P. Redick, *Biopharming, Biosafety & Billion Dollar Debacles: Preventing Liability for Biotech Crops*, 8 DRAKE J. AGRIC. L. 115 (2003) (proposing contract based stewardship regime in lieu of new regulations). I respectfully disagree and would suggest that, in light of the signal failure of criminal and tort regimes to prevent contamination to date, they are a slender reed upon which to balance food safety and the fate of the U.S. multi-billion dollar commodity export business.

pass new laws directly addressing the problems surrounding biopharming. These laws should recognize the unique nature of biopharmed crops and require development of a special regulatory system devoted to the specific challenges posed by the new technology. A statutory presumption against the use of food crops would go a long way towards curing the flaws identified in this Article. This presumption would not be irrebuttable, but could be overcome only upon a showing that use of non-food crops is technically infeasible and that the public interest at stake is important or compelling. The biopharm crop developer should have the burden of proof on each of these points. Such a rule would permit biopharming in food crops if it is truly in the public's interest, but would not permit private commercial assessments of profitability to supplant significant public safety concerns.

The existing scheme leaves the public exposed and vulnerable. There is no way to impose USDA's post hoc physical containment measures in a way that will actually be protective of the public health without also creating a cost-prohibitive and burdensome oversight system. And, even were USDA to actually institute such a detailed and omnipresent system, physical containment simply cannot be done. Cross-pollination will occur; farmers will fail to follow planting requirements; and accidents will happen. Use of food crops for biopharming therefore guarantees that at least low levels, and possibly significant quantities, of biopharmed proteins will wind up in human foods. There is no Plan B, no backup means for decontaminating the food supply. Indeed, once these crops are developed and marketed, the only possible restrictions will be extremely costly to implement and none of them can successfully protect the nation's food supply from contamination.²⁵²

V. CONCLUSION

Working within a regulatory framework largely unfettered by environmental or health and safety considerations, it is perhaps not surprising that biotech developers focused on corn as the most immediately cost-effective vehicle for their project.²⁵³ Corn is well characterized and the growing cycle is well understood.²⁵⁴ And, of course, there is the influence of corn boards and lobbies. With few regulators raising concerns about cross-fertilization and commingling, developers spent years and large sums of money developing potential corn biopharm products. Now agricultural economists pose the question "*what is the most efficient level of biosafety obtained for the cost of regulation incurred in the current system?*"²⁵⁵ This is not the proper question. The current regulatory system is not etched in stone. This Article identifies a number of regulatory measures that would permit the development of this technology while providing far more protection for the food supply.

²⁵² For example, the NRC unambiguously concluded that, with regard to producing human monoclonal antibodies in plants, "[i]t would be essential to grow these plants in restricted locations," meaning isolated from food crops. COMMITTEE ON BIOBASED INDUSTRIAL PRODUCTS, *supra* note 10, at 228.

²⁵³ See, e.g., Giddings, *supra* note 164, at 1152-54 (noting that many biotech companies use corn because of the economics of production).

²⁵⁴ RALPH E. NEILD & JAMES E. NEWMAN, NATIONAL CORN HANDBOOK: GROWING SEASON CHARACTERISTICS AND REQUIREMENTS IN THE CORN BELT, at <http://www.agcom.purdue.edu/AgCom/Pubs/NCH/NCH-40.html> (last visited June 26, 2004).

²⁵⁵ See, e.g., JOSÉ FALCK ZEPEDA ET AL., BIOTECHNOLOGY, BIOSAFETY, AND REGULATORY COSTS, at <http://www.economia.uniroma2.it/conferenze/icabr2003/abstract/> (linking to Public Perception of Biotechnology) (last visited June 26, 2004).

Decision-making about food safety necessarily entails balancing competing values and interests,²⁵⁶ but irreversible tradeoffs of this magnitude ought not be lightly made. It may be that the public is willing to accept this trade; the prospect of inexpensive and plentiful therapeutics and plastics may be attractive enough to accept the threat of contaminated food. But, such a fundamental and irrevocable choice should be the product of a public discussion²⁵⁷ and decision-making process,²⁵⁸ not the byproduct of private economic ordering. While economic efficiency is an important factor in regulation,²⁵⁹ there is an even more important preliminary question that it seems was never asked: Are there directions of research that should be categorically excluded from the beginning in order to ensure that the fruits of the research can be grown without compromising the security of the food supply?

Pressure finds the weakest spot. Had the biopharming developers been forced to internalize these public health concerns during the development process, the products now being readied for market would have confronted and solved the problems, either through use of non-food crops as a production vehicle or through an as-yet-undeveloped extensive and elaborate system of biological and geographic safeguards like those detailed in this Article. The status quo would have been protective. Instead, developers were free to build a status quo that did not include consideration of these basic human health concerns.

When baseline protective measures are added after the fact, they are always too little, too late. Even worse, the measures are viewed as changing a status quo and "adding" costs. All too often, these protective measures are considered regulatory red tape²⁶⁰—unnecessary hurdles placed between developers and their just rewards by an unresponsive and incompetent bureaucracy. Under those circumstances, developers push for compromise on the measures intended to protect public health.

Let me be clear—there are real potential advantages to this technology. It could provide a cost-effective means to produce desperately needed therapeutic proteins. Plants are not known to harbor bacterial or viral pathogens that infect humans or animals, which means that the purification risks are reduced.²⁶¹ It is simply much less likely that a human pathogen will accidentally contaminate a batch of plant-

²⁵⁶ For a general description of food safety decision-making, see Vern R. Walker, *Some Dangers of Taking Precautions Without Adopting the Precautionary Principle: A Critique of Food Safety Regulation in the United States*, 31 ENVTL. L. REP. 10040 (2001).

²⁵⁷ See Christopher H. Schroeder, *Deliberative Democracy's Attempt to Turn Politics into Law*, 65 LAW & CONTEMP. PROBS. 95 (2002) (discussing the hurdles to having such a conversation).

²⁵⁸ For a discussion of how such decision-making could, or ought to take place, see DANIEL A. FARBER, *ECO-PRAGMATISM: MAKING SENSIBLE ENVIRONMENTAL DECISIONS IN AN UNCERTAIN WORLD* 39-42 (1999).

²⁵⁹ Cost benefit analyses are now *de rigueur* for almost all agency decision-making. See Exec. Order No. 12,866, 58 Fed. Reg. 51,735 (Oct. 4, 1993). As a tool, cost-benefit analysis can be extremely informative. For questions like the ones posed in this Article, where the benefits are inchoate and the risks are probabilistic, the tool of risk benefit analysis is too often distorted or manipulated in the hands of ideologically or economically interested actors. For a recent critique of what passes for reasoned analysis in the world of cost-benefit balancing, see Frank Ackerman & Liza Heinzerling, *Pricing the Priceless: Cost Benefit Analysis of Environmental Protection*, 150 U. PA. L. R. 1553 (2002).

²⁶⁰ For an point-by-point refutation of this portrayal, and an argument that regulation of GM crops should be precautionary, see John S. Applegate, *The Prometheus Principle: Using the Precautionary Principle to Harmonize the Regulation of Genetically Modified Organisms*, 9 IND. J. GLOBAL LEGAL STUD. 207, 234 (2001).

²⁶¹ Steven J. Streatfield et al., *Plant Based Vaccines: Unique Advantages*, 19 VACCINE 2742, 2747 (2001).

grown pharmaceuticals. After the recent mad cow disease scare, this concern is a pressing one.²⁶² Grains are also easy to transport and store. Finally, the technology could ultimately result in needle-free vaccine delivery systems that do not require refrigeration or the participation of trained medical professionals.²⁶³ Thus, biopharmed vaccines might be particularly suitable for use in the developing world, and could make a reality of the dream of universal vaccination.

Without adequate safeguards, however, this technology poses imminent risks that might dwarf those benefits. It all comes down to the fact that biopharmed corn and other crops are emphatically not for consumption as food, but are indistinguishable from crops intended for food. As such, biopharming really does pose new and fundamental safety challenges. Answering those challenges will require concentrated effort and significant investment from the regulatory agencies and the regulated community. Unfortunately, there is little to suggest a real commitment to building the sort of infrastructure needed to safely grow these crops. The specter of StarLink corn and ProdiGene is hovering. The next violation may not be caught in time, and the next crisis might not be so benign.

The integrity of the U.S. food supply is at stake. With a clear likelihood of contamination and no evidence that these crops are safe to consume, even in low levels, permitting commercial development of these products cannot be justified as scientifically sound or as a reasonable assessment of the costs and benefits. And, with the European Union, Japan, and Korea (our major grain commodity partners) establishing threshold tolerance levels for GM contamination,²⁶⁴ the U.S. commodities export markets face potentially cataclysmic risks.

These failures to address the problem of contamination and commingling become even more critical now that the Cartagena Protocol on Biosafety has entered into force.²⁶⁵ Article 10 of the Protocol gives states the power to refuse import of the products of biotechnology in order to avoid or minimize adverse effects on human health or the conservation and sustainable use of biological diversity.²⁶⁶ It is hard to imagine anything more likely to trigger a refusal to import under the Cartagena Protocol than undetectable commingling of industrial or pharmaceutical crops containing non-food proteins with export food crops.

²⁶² See, e.g., Chris Clayton, *U.S. Cattle Industry Calls For Renewal of Ban on Canadian Beef*, OMAHA WORLD HERALD, May 27, 2004.

²⁶³ Streatfield, *supra* note 261.

²⁶⁴ See Peter W.B. Phillips & Heather McNeill, *A Survey of National Labeling Policies for GM Foods*, 3 J. AGROBIOTECHNOLOGY MGMT. & ECON. 219 (2000), available at <http://www.agbioforum.org/v3n4/v3n4a07-phillipsmcneill.htm#T1>.

²⁶⁵ CARTAGENA PROTOCOL ON BIOSAFETY, *supra* note 32.

²⁶⁶ *Id.* at art. 10.

Select Recent Court Decisions

Punitive Damages: Nursing Care Providers Are Not Health Care Providers for Punitive Damages Purposes—*Covenant Care, Inc., v. Superior Court of Los Angeles County*, 86 P.3d 290 (Cal. 2004).

Women's Health: Religiously Affiliated Charities Must Comply with WCEA Requirements to Offer Birth Control Insurance Coverage—*Catholic Charities of Sacramento, Inc. v. Superior Court of Sacramento County*, 85 P.3d 67 (Cal. 2004).