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## The History and Future of Genetically Modified Crops: Frankenfoods, Superweeds, and the Developing World

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# THE HISTORY AND FUTURE OF GENETICALLY MODIFIED CROPS: FRANKENFOODS, SUPERWEEDS, AND THE DEVELOPING WORLD

*Brooke Glass-O'Shea*<sup>\*</sup>

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## I. INTRODUCTION

In a 1992 letter to the New York Times, a man named Paul Lewis referred to genetically modified (GM) crops as “Frankenfood,” and wryly suggested it might be “time to gather the villagers, light some torches and head to the castle.”<sup>1</sup> Little did Lewis know

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1. Paul Lewis, Letter to the Editor, *Mutant Foods Create Risks We Can't Yet Guess; Since Mary Shelley*, N.Y. TIMES, June 16, 1992, <http://query.nytimes.com/gst/full>

that his neologism would become the rallying cry for activists around the world protesting the dangers of genetic engineering. The environmental activist group Greenpeace made great use of the “Frankenfood” epithet in their anti-GM campaigns of the 1990s, though they have since backed away from the word and the hardline stance it represents.<sup>2</sup> But genetically modified crops, like Dr. Frankenstein’s legendary creation, continue to be sadly misunderstood.

Does genetic engineering really create dangerous mutant foods? Or is it a benign technology that offers the promise of improved crop yields, decreased pesticide use, and even drought resistance to help poor countries cope with climate change? The latter position is most often associated with the United States, where over 80% of corn, cotton, soybeans, sugar beets, and canola is genetically modified.<sup>3</sup> On the other side is the European Union, where a new GM potato—only the second GM crop ever to be approved for cultivation in the EU—set off a wave of controversy last year, despite being intended for industrial use and not human consumption.<sup>4</sup> Developing countries are often caught in the middle, trying to create effective regulatory systems with activists, non-governmental organizations (NGOs), and scientists all making different (and often contradictory) claims about GM foods’ safety and utility. Frequently lost in the heat of the debate is one simple, remarkable fact: People have been eating GM foods for well over a decade, without a single case of demonstrated harm to human health.<sup>5</sup>

Section II of this paper offers a brief historical overview of agricultural innovation, including the Green Revolution and the intro-

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page.html?res=9E0CE0DD153AF935A25755C0A964958260&scp=2&sq=mutant%20foods%20create%20risks&st=cse.

2. See Paul Voosen, *Ghost of ‘Frankenfood’ Haunts Europe*, N.Y. TIMES (Oct. 21, 2009), <http://www.nytimes.com/gwire/2009/10/21/21greenwire-ghost-of-frankenfood-haunts-europe-55309.html?scp=1&sq=ghost%20of%20frankenfood&st=cse> (quoting Marco Contiero, Greenpeace’s European GM policy director, as saying, “We haven’t used the word ‘Frankenfood’ in many years . . . We’re trying with all our means to have a broader debate and a more serious debate.”).

3. See Elizabeth Weise, *Genetically Modified Foods Get U.S. Traction*, *Global Debate*, USA TODAY (Mar. 16, 2010), [http://www.usatoday.com/tech/science/2010-03-17-Biotech17\\_cv\\_N.htm?loc=interstitialskip](http://www.usatoday.com/tech/science/2010-03-17-Biotech17_cv_N.htm?loc=interstitialskip).

4. Leo Cendrowicz, *Is Europe Finally Ready for Genetically Modified Foods?* TIME (Mar. 9, 2010), <http://www.time.com/time/business/article/0,8599,1970471,00.html?xid=rss-topstories>.

5. Jose Falck-Zepeda, Anthony Cavalieri, & Patricia Zambrano, *Delivering Genetically Engineered Crops to Poor Farmers: Recommendations for Improved Biosafety Regulations in Developing Countries*, IFPRI POL’Y BRIEF, Dec. 2009, available at <http://www.ifpri.org/sites/default/files/publications/bp014.pdf>.

duction of genetically modified crops in the latter half of the 20<sup>th</sup> century. Section III discusses some of the potential effects of genetically modified crops on human health and the natural environment. Section IV describes the popular and media response to GM technology, as well as regulatory responses in the United States, European Union, and at the international level. Section V attempts to portray some of the issues and controversies surrounding GM crops in the developing world, using examples from the cases of GM eggplant and cotton in India, the development of a nutritionally-enhanced GM rice variety to combat Vitamin A deficiency, and future problems related to global climate change. Finally, Section VI concludes that the risks and benefits of GM technology must be considered within the larger context of the global commitment to fighting hunger and poverty.

For the purposes of this paper, the terms “genetic engineering,” “genetic modification,” and “gene-splicing” are used interchangeably, as they are typically used this way in both popular and academic writing.

## II. NEW CROPS: INNOVATION AND SUSPICION

### *A. Tinkering with Plants*

Humans have been experimenting with plants for thousands of years. Many of our common crops—including rice, wheat, corn, and beans—cannot reproduce themselves without human help, because we have altered them over the centuries to make them better at producing food for us.<sup>6</sup> However, despite the myriad advantages of improved agriculture, people throughout history have often been suspicious of new foods and new production methods.

For example, those new GM potatoes mentioned in Section I are really just the latest incident in a centuries-long European potato controversy. The potato was originally brought to Europe from South America by the Spanish, but the long European summer prevented the growth of large tubers, and Europeans spent the next 250 years growing potatoes solely as ornamental bushes.<sup>7</sup> In the late 18th century, Europeans still believed that potatoes caused “leprosy,

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6. See NINA V. FEDOROFF & NANCY MARIE BROWN, MENDEL IN THE KITCHEN: A SCIENTIST'S VIEW OF GENETICALLY MODIFIED FOODS 233 (2004).

7. *Id.* at 45.

cholera, scrofula, rickets, and tuberculosis,”<sup>8</sup> as well as ruining the soil.<sup>9</sup> An intrepid Frenchman, Antoine Augustin Parmentier, tried to convince his countrymen to plant potatoes so that food would be available when the wheat harvest failed, but the bad harvest and resultant famine of 1789 showed that the French were more ready to revolt than eat potatoes.<sup>10</sup>

Likewise, the practice of grafting—inserting part of a desirable fruit tree into the growing part of another tree—was condemned by many early Americans as “unnatural.”<sup>11</sup> John Chapman, the man popularly known as Johnny Appleseed, held that it was “wicked to cut up trees that way,” and forbade the recipients of his seeds to use them for grafting.<sup>12</sup> Fortunately for the American fruit industry, this view did not prevail. Without grafting, we would not have seedless oranges (because of the difficulty of growing a tree from a seedless fruit), a consistent fruit crop (because sexual reproduction yields unpredictable offspring), or the countless new fruit varieties that have been developed through experimental grafting by plant breeders.<sup>13</sup>

Grafting, however, is only one of the multifarious ways that humans have learned to tamper with plants. In the 1950s, scientists developed the technique of tissue culture cloning, which is now used to produce all of the stunning varieties of orchids available in grocery stores.<sup>14</sup> Tissue culture also produces large numbers of mutations (a phenomenon known as “somaclonal variation”), making it extremely useful for generating new plant traits.<sup>15</sup> As with any other scientific method, tissue culture techniques are constantly being adapted and refined. One recently developed culturing method for obtaining new rice mutations involves chilling the flowering tips of rice plants, disinfecting them with alcohol and Clorox, incubating them, irradiating them with gamma rays, and then growing them in test tubes, a greenhouse, and finally a field.<sup>16</sup> These new mutant va-

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8. The word “tuberculosis” comes from the Latin “tuberculum,” or small tuber, because of the characteristic small nodules found on patients’ lungs. It is not difficult to imagine how Europeans came to associate the disease with eating potatoes. See “Tuberculosis,” AMERICAN HERITAGE DICTIONARY OF THE ENGLISH LANGUAGE (4th ed. 2004), available at <http://dictionary.reference.com/browse/tuberculosis>.

9. FEDOROFF, *supra* note 6, at 23.

10. *Id.* at 23-24.

11. *Id.* at 52.

12. *Id.* at 52-3.

13. See *id.* at 53.

14. *Id.* at 11-12.

15. FEDOROFF, *supra* note 6, at 15.

16. *Id.* at 14-15.

rieties of rice may not be “natural,” but they are “conventional” in the sense that they are not considered to be genetically modified and do not require any special treatment or regulation.<sup>17</sup>

The astute reader may have noticed that the tissue culture method described above contains an additional mutation-inducing step—irradiation. The practice of treating plant parts with radiation or carcinogenic chemicals in order to induce mutation is known as “mutation breeding.”<sup>18</sup> Over 2,250 new mutant plant types have been developed in the past 70 years.<sup>19</sup> Popular examples include Calrose 76 (a staple of California rice growers), triticale (a rye-wheat hybrid good for making flour), Creso (Italy’s most popular wheat for pasta-making), and seedless watermelon.<sup>20</sup> As with tissue culture cloning, mutation breeding is considered a “conventional” plant breeding practice, and its genetically altered products may be field tested and sold “without governmental oversight or strictures.”<sup>21</sup> However, recent research indicates mutation breeding may cause more extensive changes to a plant’s genome than genetic engineering; researchers concluded “that safety assessment of improved plant varieties should be carried out on a case-by-case basis and not simply restricted to foods obtained through genetic engineering.”<sup>22</sup>

For many people, the assertion that GM crops are inherently no more risky than some non-GM crops raises a question: Can “conventional” crops be unsafe? The answer is an unambiguous “yes.” The copious natural defense mechanisms of plants include a striking variety of toxic chemicals, of which we consume roughly 5,000 to 10,000 per day.<sup>23</sup> In general, plant breeding methods have selected and bred for minimal concentrations of these toxins, but the unpredictable genetic reshuffling of conventional breeding can sometimes raise toxin levels unexpectedly. This was the case with one variety of pest-resistant celery, which gave agricultural workers rashes and turned out to have unusually high levels of carcinogenic psoralens.<sup>24</sup>

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17. *Id.* at 15.

18. PAMELA C. RONALD & RAOUL W. ADAMCHAK, *TOMORROW’S TABLE: ORGANIC FARMING, GENETICS, AND THE FUTURE OF FOOD* 88 (2008).

19. *Id.*

20. FEDOROFF, *supra* note 6, at 16-17.

21. *Id.* at 18.

22. Rita Batista et al., *Microarray Analyses Reveal that Plant Mutagenesis May Induce More Transcriptomic Changes Than Transgene Insertion*, 105 *PROC. NAT’L ACAD. SCI.* 3640 (Mar. 2008).

23. Channapatna S. Prakash, *The Genetically Modified Crop Debate in the Context of Agricultural Evolution*, 126 *PLANT PHYSIOLOGY* 8, 12 (2001).

24. *Id.*

Similarly, the newly developed Lenape potato had to be pulled from production when it was found to contain extremely high concentrations of solanine, a neurotoxin.<sup>25</sup>

In addition to their natural plant toxins, conventional crops may also carry dangers from pathogenic bacteria or parasitic fungi. Corn, for example, can develop unsafe levels of fungal toxins when pests attack the crop and bore into the ears.<sup>26</sup> The borers leave holes that can provide an ideal habitat for fungi like *Fusarium* and *Aspergillus*, which in turn produce harmful toxins (known as “mycotoxins”) that can lead to cancer and neural defects in humans.<sup>27</sup> Studies of the European corn crop have estimated that average mycotoxin levels are nine parts per million—nearly five times higher than the maximum recommended by the World Health Organization (WHO).<sup>28</sup>

### *B. The (Original) Green Revolution*

In 1943, the Mexican government and the Rockefeller Foundation collaborated to form the Office of Special Studies, with the goal of improving the yields of Mexican staple crops.<sup>29</sup> By 1948, Mexico was self-sufficient in corn production for the first time since its independence, and by the 1960s, total Mexican corn production had tripled.<sup>30</sup> A parallel wheat program, led by American scientist Norman Borlaug, was similarly successful—Mexico was self-sufficient in wheat production by the mid-1950s, and yields continued to rise dramatically over the next several decades.<sup>31</sup> In 1961, the Rockefeller and Ford Foundations collaborated with the government of the Philippines to form the International Rice Research Institute, which (along with research at China’s Academy of Agricultural Sciences) produced new rice varieties that boosted yields across Asia and Latin America.<sup>32</sup>

This tremendous growth in third world agricultural productivity came to be known as “The Green Revolution,” a term originally

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25. *Id.*

26. JENNIFER A. THOMSON, SEEDS FOR THE FUTURE: THE IMPACT OF GENETICALLY MODIFIED CROPS ON THE ENVIRONMENT 26 (Cornell Univ. Press 2007) (2006).

27. *Id.*

28. *Id.*

29. GORDON CONWAY, THE DOUBLY GREEN REVOLUTION: FOOD FOR ALL IN THE TWENTY-FIRST CENTURY 47 (Cornell Univ. Press 1998) (1997).

30. *Id.* at 47-48.

31. *Id.* at 48-49.

32. *Id.* at 51-57.

coined by William Goud, then-head of the U.S. Agency for International Development (USAID).<sup>33</sup> Though “green” is often used today to describe something environmentally beneficial, its use at the time conjured images of verdant, productive farmland.<sup>34</sup> The image was an apt one—global harvests tripled between 1950 and 1990, and the widespread famines predicted by doomsayers like biologist Paul Ehrlich did not come to pass.<sup>35</sup>

The remarkable gains of the Green Revolution, however, do not tell the whole story. For one, the Green Revolution’s improved crops rely heavily “on high inputs of water, capital, and chemical fertilizers and pesticides,” leading many critics to question the sustainability of such farming methods.<sup>36</sup> In the words of one expert, we may be “starving our descendants” in order to feed ourselves.<sup>37</sup> In the U.S., for example, farms across much of the Midwest have long relied on the massive Ogallala Aquifer for irrigation, but this non-replenishing water supply will be gone within a few decades if present rates of depletion continue.<sup>38</sup>

Also, the steady yield increases that characterized the Green Revolution have slowed in recent decades, indicating that we may be reaching the limit of these technologies.<sup>39</sup> Global grain harvests grew .5% per year on average during the 1990s, compared with 2.1% per year during the period of 1950-1990 (the height of the Green Revolution).<sup>40</sup> Over the twentieth century, scientists and plant breeders raised the harvest index (the ratio of grain weight to total plant weight) of many crops from around 0.25 to nearly 0.5, but 0.6 or 0.65 may be the biological limit—plants still need their leaves and roots in order to grow.<sup>41</sup> Similarly, plants can only absorb so much fertilizer before the soil begins to lose organic matter, lowering its nitrogen-holding capacity and causing excess nitrogen compounds to run off into rivers and groundwater.<sup>42</sup>

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33. *Id.* at 46.

34. CONWAY, *supra* note 29, at 46.

35. RICHARD MANNING, *FOOD’S FRONTIER: THE NEXT GREEN REVOLUTION* 4 (2000).

36. *Id.* at 5.

37. *Id.* (quoting Timothy Reeves, former director general of the International Center for the Improvement of Wheat and Maize, the research institute that grew out of Norman Borlaug’s work in Mexico).

38. *Id.* at 9.

39. *Id.* at 5-6.

40. MANNING, *supra* note 35, at 4-5.

41. Charles Mann, *Reseeding the Green Revolution*, *SCIENCE*, Aug. 22, 1997, at 1038, 1042.

42. *Id.*



### C. *The Introduction of Genetic Modification*

In the early 1970s, geneticist Stanley Cohen and biochemist Herbert Boyer discovered a mutual interest in taking apart DNA and putting it back together again.<sup>43</sup> Boyer's lab had isolated an important pair of enzymes—one could cut strands of DNA apart, and the other could “glue” them together.<sup>44</sup> Cohen, who was doing work at Stanford with tiny rings of bacterial DNA called “plasmids,” realized that Boyer's enzymes could be used to cut open one plasmid and glue a piece from another plasmid inside.<sup>45</sup> The shuffled, or “recombinant,” DNA could then be put back into bacteria, and the scientists would see if the bacterial cells expressed the newly inserted genetic trait.<sup>46</sup> For their experiment, they chose to glue in a piece of plasmid that conferred resistance to a specific antibiotic; if the test bacteria survived exposure to the antibiotic, they would know that the foreign piece of DNA had been taken up and integrated into the bacteria's DNA.<sup>47</sup>

The simple methods pioneered by Cohen and Boyer came to be known by a number of terms, including “gene-splicing,” “genetic engineering,” and “molecular cloning.”<sup>48</sup> The two scientists called their new creations “chimeras” in honor of the mythological Greek monster with a lion's head, goat's body, and serpent's tail, and because, as Cohen wrote, they “were the molecular counterparts of hybrid plant chimeras produced by agricultural grafting.”<sup>49</sup> Boyer went on to use the new gene-splicing method to develop *E. coli* bacteria that could express the gene coding for human insulin production.<sup>50</sup> The resulting drug, a form of insulin known by the brand name Humulin, became the first-ever genetically engineered therapeutic drug to be approved and commercialized,<sup>51</sup> and is now taken regularly by millions of diabetics worldwide.<sup>52</sup>

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43. FEDOROFF, *supra* note 6, at 109.

44. *Id.* at 110.

45. *Id.*

46. *Id.*

47. *Id.*

48. FEDOROFF, *supra* note 6, at 110-11.

49. *Id.* at 110.

50. *Id.* at 111.

51. HENRY I. MILLER & GREGORY CONKO, *THE FRANKENFOOD MYTH: HOW PROTEST AND POLITICS THREATEN THE BIOTECH REVOLUTION* 13 (2004).

52. *Recombinant DNA: Example Using Insulin*, IOWA PUB. TELEVISION, <http://www.iptv.org/explore-more/ge/what/insulin.cfm> (last visited Mar. 2, 2011).

Biotechnology companies targeted the first generation of GM crops at farmers, with features such as pest resistance and herbicide tolerance.<sup>53</sup> The first pest-resistance gene to be isolated and used was from *Bacillus thuringiensis* (commonly known as “Bt”), a soil bacterium that naturally produces proteins that are toxic to certain insects.<sup>54</sup> Conventional pesticides made from Bt are widely used by organic farmers,<sup>55</sup> and are considered so safe for humans that growers are not required to wash them off of crops.<sup>56</sup> By inserting a Bt gene into a crop plant like corn or cotton, the plant can be made to produce its own pest-resistant proteins, thus reducing the financial and environmental costs of spray-on pesticides.<sup>57</sup>

The overall results of using a Bt crop vary extensively by region, crop, pest infestation level, and prevailing pest-control practices.<sup>58</sup> Field corn (corn grown for animal feed or processed food) is not generally treated with pesticides “because there is some market tolerance for insect damage,” meaning that no one will notice if the crop has some worm-holes.<sup>59</sup> Also, spray-on pesticides are not very effective against the European corn borer caterpillar—a major pest in U.S. cornfields—because, once the caterpillars are inside of the plant, the sprays cannot reach them.<sup>60</sup> Thus, switching to Bt field corn generally raises yields (because of lessened crop damage) instead of lowering pesticide use.<sup>61</sup>

At the other end of the spectrum is cotton, which alone accounts for roughly 25% of global agricultural insecticide use.<sup>62</sup> Field studies in India found that farmers growing Bt cotton enjoyed higher yields while cutting their insecticide use nearly 70%.<sup>63</sup> In China, the incidence of pesticide-related farmer illness declined by

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53. PERRY JOHNSON-GREEN, INTRODUCTION TO FOOD BIOTECHNOLOGY 92 (2002).

54. *Id.* at 103.

55. *Id.*

56. FEDOROFF, *supra* note 6, at 193.

57. JOHNSON-GREEN, *supra* note 53, at 103.

58. *See, e.g.*, DOUG GURIAN-SHERMAN, UNION OF CONCERNED SCIENTISTS, FAILURE TO YIELD: EVALUATING THE PERFORMANCE OF GENETICALLY ENGINEERED CROPS 17-19 (2009) (discussing field research on the relationships between yield, corn borer infestation levels, and pesticide application for Bt and non-Bt corn varieties).

59. FEDOROFF, *supra* note 6, at 211.

60. *Id.*

61. *Id.* at 212.

62. THOMSON, *supra* note 26, at 8.

63. *Id.* at 9.

75% after the introduction of Bt cotton in 1997.<sup>64</sup> Recently, however, the proliferation of non-target insects has forced Chinese cotton farmers to increase their application of pesticides.<sup>65</sup> Though the increase has been much smaller than the overall reductions from Bt cotton, there is still concern that these “secondary” pests (bollworms are considered the primary cotton pest in China, while mirids have become a major secondary pest) could undermine some of the benefits obtained from using Bt cotton seed.<sup>66</sup> Proposed solutions include a genetically engineered “fusion protein” with a broader range of target insects than Bt alone,<sup>67</sup> as well as organic farming strategies like crop rotation and use of natural insect predators.<sup>68</sup>

### III. HEALTH AND ENVIRONMENTAL EFFECTS OF AGRICULTURAL GM TECHNOLOGY

#### *A. Effects on Human Health*

Today, GM ingredients can be found in approximately 70% of processed foods sold in the United States.<sup>69</sup> Remarkably, even with this high level of consumption, there have been no cases of demonstrated harm to humans from eating GM foods.<sup>70</sup>

As many scientists have pointed out, the risks inherent to GM technology are not fundamentally different from the risks inherent to modern crop breeding generally.<sup>71</sup> This is no longer a controversial assertion, having been endorsed by the U.S. National Academy of Sciences,<sup>72</sup> the National Research Council,<sup>73</sup> the American Medical

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64. Pamela Ronald, *What if Organic Farmers Joined Forces with Genetic Engineers?* CONSERVATION, July-Sept. 2008, at 34, available at <http://www.conservationmagazine.org/2008/08/the-problem-of-what-to-eat/>.

65. *Id.*

66. Zi-jun Wang et al., *Bt Cotton in China: Are Secondary Insect Infestations Offsetting the Benefits in Farmer Fields?* 8 AGRIC. SCI. CHINA 83 (Jan. 2009).

67. Luke Mehlo et al., *An Alternative Strategy for Sustainable Pest Resistance in Genetically Enhanced Crops*, 102 PROC. NAT'L ACAD. SCI. 7812 (May 2005).

68. Ronald, *supra* note 64, at 37-38; Shenghui Wang, David R. Just & Per Pinstrup-Andersen, *Bt-Cotton and Secondary Pests*, 10 INT'L J. BIOTECHNOLOGY 113 (May 2008).

69. Ronald, *supra* note 64, at 38.

70. *Id.*; see also Falck-Zepeda, *supra* note 5.

71. MILLER, *supra* note 51, at 37-40.

72. NAT'L ACAD. SCI., INTRODUCTION OF RECOMBINANT DNA-ENGINEERED ORGANISMS INTO THE ENVIRONMENT: KEY ISSUES 6 (1987) (“The risks associated with the introduction of R-DNA-engineered organisms are the same in kind as those

Association,<sup>74</sup> and the Royal Society (Britain's Academy of Sciences).<sup>75</sup> In 2004, the National Academies<sup>76</sup> were asked by the U.S. Department of Agriculture, the Food and Drug Administration (FDA), and the Environmental Protection Agency to compare the health risks of GM foods with those of conventionally developed foods.<sup>77</sup> They concluded that "the most genetically disruptive" method of crop development was not gene splicing, but mutagenesis (mutation breeding, discussed in Section IIA above).<sup>78</sup>

This conclusion should not be surprising, considering the relative precision of genetic engineering processes. While mutation breeding uses radiation or chemicals to try to induce random changes in a plant's DNA, "direct introduction of one or a few genes into crops results in subtle and less disruptive changes that are relatively specific and predictable."<sup>79</sup> Conventional plant breeders must introduce whole sections of unknown genetic material into a target plant, possibly including unwanted genes that produce allergens or toxins,<sup>80</sup> as with the toxic Lenape potato. Though it is possible for genetic engineering to introduce allergenic proteins into newly developed crops, the risks "are believed to be similar to those associ-

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associated with the introduction into the environment of unmodified organisms and organisms modified by other genetic techniques.").

73. NAT'L RESEARCH COUNCIL, FIELD TESTING GENETICALLY MODIFIED ORGANISMS: FRAMEWORK FOR DECISIONS 3 (1989) ("Crops modified by molecular and cellular methods should pose risks no different from those modified by classical genetic methods for similar traits.").

74. AM. MED. ASSOC., REPORT 10 OF THE COUNCIL ON SCIENTIFIC AFFAIRS: GENETICALLY MODIFIED CROPS AND FOODS, (2000), *available at* <http://www.ama-assn.org/ama/no-index/about-ama/13595.shtml> ("Federal regulatory oversight of agricultural biotechnology should continue to be science-based and guided by the characteristics of the plant, its intended use, and the environment into which it is to be introduced, not by the method used to produce it.").

75. Press Release, The Royal Soc'y, Where is the Evidence that GM Foods are Inherently Unsafe, Asks Royal Society (May 8, 2003), *available at* <http://royalsociety.org/News.aspx?id=1010&terms=gm+crops> (asserting that, after an extensive review of existing research, no credible evidence had emerged to indicate that GM foods are more dangerous to human health than non-GM foods).

76. Composed of the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and the National Research Council. *See About Us*, NATIONALACADEMIES.ORG, <http://www.nationalacademies.org/about/> (last visited Mar. 31, 2011).

77. THE NAT'L ACAD., SAFETY OF GENETICALLY ENGINEERED FOODS: APPROACHES TO ASSESSING UNINTENDED HEALTH EFFECTS 2 (2004).

78. *Id.* at 4.

79. Prakash, *supra* note 23, at 11.

80. *Id.*

ated with conventional breeding methods,” and new GM crops are subjected to a complex allergenicity assessment process.<sup>81</sup>

Some GM traits may even make crops safer to eat by protecting plants against disease and pests. Bt corn, for example, is less susceptible to borer pests than conventional corn, leading to less ear damage and lower levels of fungal toxins.<sup>82</sup> In Europe, Bt corn was found to have mycotoxin levels below the WHO’s acceptable limit, in contrast with non-Bt corn, which had levels over six times higher—well over the limit.<sup>83</sup> This difference is likely to be even greater in tropical and subtropical climates, which are more conducive to the *Fusarium* fungus.<sup>84</sup>

Genetic engineering can also be used deliberately to make foods safer. In 2003, a team of scientists used genetic engineering to remove a common allergenic protein from a line of soybean plants.<sup>85</sup> The target protein, known as “Gly m Bd 30 K,” is responsible for over 65% of allergic reactions to soy products, yet traditional breeding methods have failed to find a way to remove or suppress it.<sup>86</sup> The scientists noted that the increasing use of soybean products in processed foods has made it difficult for allergic individuals to avoid eating soy, and that infants are usually given soy-based formula if they exhibit milk sensitivity.<sup>87</sup>

### B. Environmental Effects

Many critics of GM technology have expressed concern about the effects of GM crops on the environment. As with health-related concerns, it is important to bear in mind that the environmental risks associated with GM crops are basically the same as those of agriculture in general.<sup>88</sup> This is not to say that there are no risks; human food production is almost always an “ecologically demanding endeavor.”<sup>89</sup> The point is merely that issues like gene flow and agri-

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81. AM. MED. ASSOC., *supra* note 74.

82. FEDOROFF, *supra* note 6, at 197.

83. THOMSON, *supra* note 26, at 26.

84. See FEDOROFF, *supra* note 6, at 197.

85. Eliot M. Herman et al., *Genetic Modification Removes an Immunodominant Allergen from Soybean*, 132 PLANT PHYSIOLOGY 36, 37 (2003).

86. *Id.* at 36-37.

87. *Id.* at 36, 39.

88. See Prakash, *supra* note 23, at 13.

89. *Id.*

cultural biodiversity were with us long before the introduction of genetic engineering.<sup>90</sup>

“Gene flow” refers to the transfer of genes through cross-pollination from a crop species to nearby wild or domesticated relatives.<sup>91</sup> This can lead to increased weediness in the wild plant or to “genetic swamping,” in which the new hybrid plant threatens to replace its wild parent.<sup>92</sup> Gene flow may be an issue when a crop is wind- or insect-pollinated (some crops, such as wheat, are self-pollinating<sup>93</sup>), planted near a wild relative, and endowed with traits that are advantageous in the wild.<sup>94</sup> Weediness and genetic swamping have at times posed serious problems for conventional agriculture, although not yet for GM crops.<sup>95</sup> Nevertheless, it is important to consider the gene-flow implications of any newly introduced crop, and take precautionary measures when necessary.<sup>96</sup> One simple measure is to refrain from growing a crop in an area where its wild relatives are present. Mexico, for example, placed a moratorium on the planting of GM corn while continuing to conduct research into its possible effects on Mexican corn varieties and on teosinte (corn’s wild ancestor), which is native to Mexico.<sup>97</sup> However, in countries like Peru, where poor farmers grow potato crops in close proximity to their wild relatives, other solutions may be employed to control gene flow.<sup>98</sup> One Peruvian study found that gene flow could be effectively prevented from a pest-resistant GM potato by using only sterile male cultivars, which produce no viable pollen.<sup>99</sup> While some gene flow from GM crops is inevitable, it has yet to create any major

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90. *Id.*

91. *See* THOMSON, *supra* note 26, at 80.

92. *Id.*

93. *Id.*

94. Prakash, *supra* note 23, at 13.

95. THOMSON, *supra* note 26, at 80-81 (noting the documentation of genetic swamping in Taiwanese wild rice and Galapagos Islands cotton, as well as weediness problems with wild European beets).

96. Prakash, *supra* note 23, at 13.

97. THOMSON, *supra* note 26, at 80, 85. In 2009, Mexico completed its biotechnology regulatory framework, allowing the country to lift its moratorium. Later that year, the Mexican Agriculture Ministry and Ministry of Environment granted permission to Monsanto to begin small-scale trials of GM corn in Sonora. *See* Press Release, Monsanto, Monsanto Receives Approval for Corn Field Trials in Mexico (Oct. 22, 2009), *available at* <http://monsanto.mediaroom.com/index.php?s=43&item=760>.

98. THOMSON, *supra* note 26, at 83.

99. *Id.* at 83-84.

problems for farmers, let alone the “superweeds” conjured up by GM opponents.<sup>100</sup>

Biological diversity is another major concern for the intersection between GM crops and the environment. GM technology could reduce crop diversity if it follows the Green Revolution path, wherein, for example, a handful of rice varieties were improved and exported to rice growers everywhere.<sup>101</sup> When locally developed varieties, often called “landraces,” are abandoned in favor of an improved variety, their invaluable genetic diversity can be lost unless it is stored in a seed bank or gene bank.<sup>102</sup> On the other hand, genetic engineering can also be used to preserve crop diversity, because landraces that are susceptible to a problem like drought or blight can be made viable again with the insertion of one or two genes.<sup>103</sup> This important work will have to be done by public institutions, however, as there is little profit to be had in improving crops for farmers who save and replant their own seeds, as the poor subsistence farmers who grow landraces do.<sup>104</sup>

Agriculture also affects the biodiversity of wild species, primarily through destruction of natural habitats.<sup>105</sup> The American state of Iowa, for example, has lost over 99% of its original natural habitat area, mostly through conversion to farmland.<sup>106</sup> In South Dakota, the introduction of a new drought-tolerant soybean has precipitated the conversion of over a million acres of dry grassland habitat into soybean farms.<sup>107</sup> Drought tolerance, however, “can just as easily come from conventional plant breeding” as from genetic engineering.<sup>108</sup> On balance, GM crops are likely to have a net positive impact on wild biodiversity by easing the pressure to convert more land to farms (through higher-yielding varieties), reducing the use of broad-spectrum pesticides (through targeted pest-resistance), and reducing soil tillage (through engineered herbicide tolerance).<sup>109</sup>

This last feature—herbicide tolerance—is the single most popular GM trait.<sup>110</sup> Though plant breeders have developed herbicide-

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100. *Id.* at 86-87.

101. MANNING, *supra* note 35, at 189.

102. THOMSON, *supra* note 26, at 23-24.

103. Prakash, *supra* note 23, at 13.

104. *See* THOMSON, *supra* note 26, at 21, 29.

105. *Id.* at 68.

106. MANNING, *supra* note 35, at 201.

107. *Id.*

108. *Id.*

109. THOMSON, *supra* note 26, at 71.

110. *Id.* at 40.

tolerant varieties through conventional breeding, Monsanto developed the first GM variety specifically for its own Roundup brand of herbicide, also known as glyphosate.<sup>111</sup> The resulting “Roundup Ready” crops can be treated with glyphosate to control weeds, with no harm to the crop itself. Britain’s Royal Society has conducted extensive farm-scale research on GM herbicide-tolerant crops, and concluded that they can be either better or worse for on-farm biodiversity than conventional crops, depending on how they are grown.<sup>112</sup> The researchers emphasized that the differences they found between the GM and conventional crops were not the direct result of GM technology, but rather of farmers’ different strategies for weed control.<sup>113</sup> Where the GM crops, combined with their specific herbicide, proved more effective than conventional strategies, the fields had fewer weeds, and therefore lower populations of the insects and birds that use the weeds for food and refuge.<sup>114</sup> The GM corn, however, supported more biodiversity than its conventional counterpart, which was treated with a more persistent, toxic herbicide than that applied to the GM crop.<sup>115</sup> Frequent soil tillage (plowing), another conventional weed control strategy, can also harm biodiversity by disrupting or killing soil organisms and exacerbating soil erosion (leading to runoff pollution of freshwater sources).<sup>116</sup>

#### IV. POPULAR AND REGULATORY RESPONSES

According to the Prince of Wales, genetically engineering crops to improve food production “will be guaranteed to cause the biggest disaster environmentally of all time.”<sup>117</sup> This recent comment expands on the Prince’s view, expressed in 1998, that “genetic modification takes mankind into realms that belong to God, and to God

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111. Glyphosate is “a broad-range herbicide that is practically non-toxic to organisms other than plants.” *Id.*

112. Pres Release, The Royal Soc’y, Results of GM Farm Trials Have Been Misrepresented, Says Lord May (Nov. 25, 2003), available at <http://royal-society.org/News.aspx?id=1183&terms=genetically+modified+crops>.

113. THOMSON, *supra* note 26, at 43-44.

114. *Id.* at 43.

115. *Id.*

116. *Id.* at 44-45.

117. *Prince Charles: GM Crops Would Be ‘Biggest Ever Environmental Disaster’*, THE TIMES ONLINE (Aug. 13, 2008), <http://www.timesonline.co.uk/tol/news/environment/article4520568.ece>.



alone.”<sup>118</sup> The British general public seems to agree with the Prince; protesters in the UK regularly sabotage field trials of GM crops, and scientists have had to ask the government for better protection of their research sites.<sup>119</sup>

The Bulgarian government effectively banned GM crops in March 2010, citing “public fears.”<sup>120</sup> A state-funded survey there reported that 97% of Bulgarian citizens were opposed to genetically modified organisms.<sup>121</sup> Leaders in Zambia and Zimbabwe turned away emergency food aid during a drought crisis in 2002 because the shipment contained GM corn; the president of Zambia stated that his people may be hungry, but he would not feed them poison.<sup>122</sup> As the UN World Food Programme was trying to take the shipment back, it was raided by a desperate group of starving villagers, who made off with thousands of bags of food.<sup>123</sup>

Even in the United States, opposition to GM food is extremely common. A 2005 survey by the Pew Initiative reported that half of Americans “would oppose the introduction of genetically modified foods into the U.S. food supply,” despite GM foods having been in the U.S. food supply since 1996.<sup>124</sup> Perhaps unsurprisingly, another 2005 survey found that two-thirds of American consumers did not know that U.S. stores sold GM foods.<sup>125</sup> U.S. Congressman Dennis Kucinich has stated that genetic engineering “is not the same as conventional growth of food. It’s a manmade process. It has nothing to do with the ways of nature. It’s very violent.”<sup>126</sup> American activist Jeremy Rifkin has compared genetic engineering to nuclear holocaust.<sup>127</sup>

If GM foods pose no special risks to human health or the environment, why are people so afraid of them? One reason is simply

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118. Robert Booth, *Charles Warns GM Farming Will End in Ecological Disaster*, THE GUARDIAN (Aug. 13, 2008), <http://www.guardian.co.uk/environment/2008/aug/13/prince.charles.gm.farming>.

119. *Prince Charles*, *supra* note 117.

120. Irina Ivanova, *Bulgaria Parliament Bans GMO Crops to Soothe Fears*, REUTERS (Mar. 18, 2010), <http://www.reuters.com/article/2010/03/18/us-bulgaria-gmo-idUSTRE62H3EJ20100318>.

121. *Id.*

122. ROBERT PAARLBERG, STARVED FOR SCIENCE: HOW BIOTECHNOLOGY IS BEING KEPT OUT OF AFRICA 14-15 (2008).

123. *Id.* at 15.

124. *Id.* at 22.

125. *Id.* at 23.

126. FEDOROFF, *supra* note 6, at 10.

127. Paul S. Naik, *Biotechnology Through the Eyes of an Opponent: The Resistance of Activist Jeremy Rifkin*, 5 VA. J.L. & TECH. 5 (2000).

that they are portrayed in the media as fundamentally different from regular foods, and (as discussed in Section II) people are often suspicious of any changes to their food supply. Exacerbating the problem is the fact that much of the general public is surprisingly ignorant about some of the basic facts of biology. For example, a 2004 telephone survey by Rutgers University's Food Policy Institute found that 43% of Americans believed that non-GM tomatoes do not contain genes, while one third believed "that eating genetically modified fruit would change their own genes."<sup>128</sup>

Another possible explanation is that, without the labeling of foods that contain GM ingredients, consumers cannot know or control whether or not they eat such foods. In the U.S., 94% of consumers say they want GM foods to be labeled as such.<sup>129</sup> However, as plant geneticist Pamela Ronald observes, GM food labels may encourage unwarranted suspicion without providing any useful information.<sup>130</sup> Ronald's observation is borne out by the experience of Europe, where opposition to GM foods remains even higher than in the U.S., despite mandatory labeling and strict regulation.<sup>131</sup> As Henry I. Miller, former director of the FDA's Office of Biotechnology, has noted, "People naturally assume that something that is more highly regulated is more dangerous. Government officials should have done less regulating and more educating."<sup>132</sup>

According to Miller, who seeks to dispel "the Frankenfood Myth" in his book of the same name, the problem started in 1975, when scientists held a conference in Pacific Grove, California, to discuss the risks of the new gene-splicing technology.<sup>133</sup> The media seized upon the event as evidence of a biotech menace, and some of the conference-goers felt that strict regulation was called for in order to reassure the public, even if the actual risks were minimal.<sup>134</sup> Nobel laureate James Watson, one of the conveners of the con-

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128. Jane E. Brody, *Facing Biotech Foods Without the Fear Factor*, N.Y. TIMES (Jan. 11, 2005), [http://www.nytimes.com/2005/01/11/health/11brod.html?pagewanted=1&\\_r=1](http://www.nytimes.com/2005/01/11/health/11brod.html?pagewanted=1&_r=1).

129. PAARLBERG, *supra* note 122, at 23.

130. See RONALD & ADAMCHAK, *supra* note 18, at 97-98; see also AM. MED. ASSOC., *supra* note 74 ("The AMA believes that as of December 2000, there is no scientific justification for special labeling of genetically modified foods, as a class, and that voluntary labeling is without value unless it is accompanied by focused consumer education.").

131. PAARLBERG, *supra* note 122, at 23-24.

132. Brody, *supra* note 128.

133. MILLER & CONKO, *supra* note 51, at 10.

134. *Id.*

ference, later wrote that many of the assembled scientists were left feeling that the group had succumbed to media pressure instead of using their scientific judgment.<sup>135</sup> By 1978, Stanley Cohen, who participated in the Asilomar conference, expressed regret over its outcome, stating that the scientists' "initial concerns were both overblown and foolish."<sup>136</sup>

In 1982, the first drug produced with GM technology came up for approval by the U.S. FDA.<sup>137</sup> The FDA determined that the new technology was "no more than an extension, or refinement, of long-used and familiar methods for the genetic improvement of organisms for various products and purposes," and approved the drug in only five months (the average FDA approval at the time took 30.5 months).<sup>138</sup> The drug was human insulin, produced by Herbert Boyer's company, Genentech.

Due to the peculiarities of the American regulatory system, the FDA is not the only agency that oversees the approval of GMOs (genetically modified organisms). The U.S. Department of Agriculture (USDA) regulates any new plants or bacteria that are "likely to become a pest," including all organisms with DNA from more than one genus (which effectively encompasses all GMOs).<sup>139</sup> A GM crop developer "must obtain a permit for field tests and, after several years of tests, petition APHIS [USDA's Animal and Plant Health Inspection Service] to 'deregulate' the new crop."<sup>140</sup> The Environmental Protection Agency (EPA) also regulates many GM crops, under the reasoning that they are "new" (a designation that has only been applied to GM crops) and may produce insecticides (such as Bt) or other "chemicals" (e.g. by fixing nitrogen).<sup>141</sup> Unlike the FDA, the USDA and EPA have chosen to treat GMOs as though they are inherently more dangerous than other agricultural products,<sup>142</sup> although, according to geneticist and molecular biologist Nina Fedoroff, such a distinction "makes no biological sense."<sup>143</sup>

The U.S. system for regulating GM crops might bear some improvement, but the European system is much worse. Europe has a

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135. *Id.* at 10-11.

136. Jack Anderson, *Rules Hamper Genetic Research*, TOLEDO BLADE, June 14, 1978, at 21.

137. MILLER & CONKO, *supra* note 51, at 13.

138. *Id.*

139. FEDOROFF, *supra* note 6, at 146-47.

140. *Id.* at 147.

141. *Id.* at 147-48.

142. MILLER & CONKO, *supra* note 51, at 14-15.

143. FEDOROFF, *supra* note 6, at 149.

separate and stricter regime for GM products, which is based on a conservative interpretation of the precautionary principle.<sup>144</sup> This idea, drawn from environmental policy, holds that “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”<sup>145</sup> The precautionary principle gained a great deal of traction in the 1990s, when it was incorporated into over a dozen international environmental treaties.<sup>146</sup> However, according to political scientist Robert Paarlberg, the principle has gradually shifted over time “from justifying technological precaution in the face of a documented harm to justifying technological prohibition simply under any uncertainty, without evidence of risk.”<sup>147</sup>

By the late 1990s, mad cow disease and a number of other health scares had left Europeans feeling cautious about their food supply, distrustful of regulators, and wary of any new risks real or imagined.<sup>148</sup> In 1998, the European Community (EC) placed a moratorium on approval of any new GM crops, which was eventually struck down by the World Trade Organization (WTO) after being challenged by the U.S., Canada, and Argentina.<sup>149</sup> The WTO panel found that European safeguard measures for GM foods were based on improper risk assessments “and hence could be presumed to be

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144. PAARLBERG, *supra* note 122, at 118-19.

145. Andrew W. Torrance, *Intellectual Property as the Third Dimension of GMO Regulation*, 16 KAN. J.L. & PUB. POL'Y 257, 273 (2007) (quoting REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (UNCED), June 3-14, 1992, *Rio Declaration on Environment and Development*, Principle 15, U.N. Doc A/CONF.151/26 (Vol. I) (Aug. 12, 1992)).

146. Ragnar E. Löfstedt et al., *Precautionary Principles: General Definitions and Specific Applications to Genetically Modified Organisms*, 21 J. POL'Y ANALYSIS & MGMT. 381, 384-85 (Summer 2002).

147. PAARLBERG, *supra* note 122, at 119-20.

148. Löfstedt, *supra* note 146, at 385 (pointing to “Chernobyl, Brent Spar, BSE [mad cow disease] in British (and, now, European and Japanese) beef, dioxin in Belgian chicken feed, and contaminated blood in France”); *see also* Torrance, *supra* note 145, at 270 (noting that a discredited study purporting to show that GM potatoes were toxic to rats “may have soured a European citizenry already distrustful of food safety in the wake of the outbreak of Bovine spongiform encephalopathy (BSE), or mad cow disease, to the palatability of GM food”).

149. *See* Debra M. Strauss, *Feast or Famine: The Impact of the WTO Decision Favoring the U.S. Biotechnology Industry in the EU Ban of Genetically Modified Foods*, 45 AM. BUS. L.J. 775, 785-86 (2008).

maintained without sufficient scientific evidence.”<sup>150</sup> In 2010, the EC finally cleared its second-ever GM crop—a potato not intended for human consumption, noted in Section I—after a seven-year approval process.<sup>151</sup> Martin Haeusling, a member of the EU Parliament, decried the decision, claiming that 70% of Europeans are still opposed to GM crops.<sup>152</sup>

Europeans have also exported their anti-GM views and regulations to Africa, where half of all foreign aid comes from the EU or EU member states.<sup>153</sup> European donor agencies have supported anti-GM campaigns and strict GMO regulations in Africa, while offering little for improvement of agricultural productivity.<sup>154</sup> Africa also remains heavily dependent on agricultural exports to Europe, which might be threatened by any hint of “contamination” with GM genes.<sup>155</sup> Zambia’s rejection of GM food aid in 2002, for example, was urged by exporters like Agriflora Ltd., an international company growing organic vegetables in Zambia for export, whose “main selling point is that Zambia is GM free.”<sup>156</sup> European NGOs like Greenpeace International and Friends of the Earth, after successfully campaigning against GM crops at home, have expanded their anti-GM operations to the developing world, demonizing GM crops and technology as a sinister American scheme to poison or enslave the poor.<sup>157</sup>

At the international level, the WHO reported in 2005 that “15 legally binding [international] instruments and non-binding codes of practice address some aspect of GMO regulation or trade. Such sector-based regulations increase the already overstretched capacity of developing countries, and present challenges to develop a fully coherent policy and regulatory framework for modern biotechnol-

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150. Torrance, *supra* note 145, at 266-67 (quoting World Trade Organization, Dispute Settlement, *European Communities - Measures Affecting the Approval and Marketing of Biotech Products*).

151. *GM Potato Cleared for EU Farming*, BBC NEWS (Mar. 2, 2010), <http://news.bbc.co.uk/2/hi/8545503.stm>.

152. *GM Potato to be Grown in Europe*, THE GUARDIAN (Mar. 3, 2010), <http://www.guardian.co.uk/environment/2010/mar/03/eu-approves-gm-food-potato>.

153. PAARLBERG, *supra* note 122, at 122-24.

154. *Id.* at 125-26.

155. *Id.* at 134-36.

156. *Id.* at 135-36 (quoting Robert Munro, General Manager of Vegetables at Agriflora).

157. *See id.* at 138-46.

ogy.”<sup>158</sup> The UN Environment Programme (UNEP) has attempted to address this problem by providing funding, advising, and workshops to help poor countries create National Biosafety Frameworks under the 2000 Cartagena Protocol on Biosafety.<sup>159</sup> Unfortunately, the UNEP program has actively promoted strict European-style regulatory systems.<sup>160</sup> The program’s bias has had the strongest effect in Africa, where many governments lack the experience and independent technical expertise to evaluate and challenge the claims of European donors.<sup>161</sup> Pioneering plant biologist Ingo Potrykus condemns this “EU regulation-creep”<sup>162</sup> in blunt terms: “The damage to lives and welfare from GMO-regulation are enormous and affect the poor, and not the rich Western societies, which are responsible for the GMO-hysteria . . . There is no scientific justification for the world-wide established regulatory system based on the concept of ‘extreme precautionary approach.’ ”<sup>163</sup>

Robert Paarlberg offers a simple explanation for why citizens of rich, developed countries remain so resistant to GM food technology: GM foods have offered no benefits to them.<sup>164</sup> Europe and the United States have become so agriculturally productive that the marginal benefits of increasing productivity even more are seen as minimal, and easily outweighed by the social costs of industrialized agriculture—environmental pollution from pesticides and fertilizers, and loss of small family farms and the traditions they represent.<sup>165</sup> Furthermore, the efficiency gains from GM crops are largely retained by farmers and seed companies, leaving consumers with little

158. FOOD SAFETY DEP’T, WORLD HEALTH ORG., MODERN FOOD BIOTECHNOLOGY, HUMAN HEALTH AND DEVELOPMENT: AN EVIDENCE-BASED STUDY iv (2005), available at [http://www.who.int/foodsafety/publications/biotech/biotech\\_en.pdf](http://www.who.int/foodsafety/publications/biotech/biotech_en.pdf).

159. PAARLBERG, *supra* note 122, at 130; see also SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY, WORLD TRADE CENTER, CARTAGENA PROTOCOL ON BIOSAFETY TO THE CONVENTION ON BIOLOGICAL DIVERSITY I (2000), available at <http://www.cbd.int/doc/legal/cartagena-protocol-en.pdf>.

160. PAARLBERG, *supra* note 122, at 130-32.

161. *Id.* at 131-32 (noting that, of the twenty three African countries to complete the UNEP program, twenty one chose the strictest possible level of regulation, compared with only one of eighteen Asian countries and one of eight Latin American countries).

162. The term is borrowed from Temba Nolutshungu, *Question of Life or Death in Africa*, THE STANDARD (Feb. 8, 2006), [http://www.thestandard.com.hk/news\\_detail.asp?pp\\_cat=20&art\\_id=11510&sid=6566019&con\\_type=1](http://www.thestandard.com.hk/news_detail.asp?pp_cat=20&art_id=11510&sid=6566019&con_type=1).

163. I. Potrykus, *Lessons from Golden Rice on Public Sector Responsibility and Failure*, 25S NEW BIOTECHNOLOGY S321 (2009).

164. PAARLBERG, *supra* note 122, at 1.

165. See *id.* at ch. 2 *passim*.

cost savings to offset the perceived risk.<sup>166</sup> But while conservative food policies may make sense in Europe, where safe, nutritious food is abundant and affordable, the same policies may prove disastrous for the developing world.

## V. GM CROPS AND DEVELOPING COUNTRIES

By 2008, 13.3 million farmers in twenty-five countries worldwide were growing GM crops.<sup>167</sup> Over 90% of these were small farmers in developing countries.<sup>168</sup> The following three case studies are intended to illustrate some of the political, social, and technical issues facing GM crops in the developing world.

### A. *Growing GM Crops in a Developing Country: Bt Eggplant and Cotton in India*

Last year, India halted plans to commercialize what would have been its first GM food crop, an eggplant known as Bt brinjal.<sup>169</sup> The Indian Environment Minister, Jairam Ramesh, cited a lack of scientific consensus and intense public opposition among his reasons for the eggplant moratorium.<sup>170</sup> Rajesh Kumar, an Indian farmer who grows brinjal, denounced the decision in an op-ed piece in *The Wall Street Journal*, asserting that the Minister had “bowed to political pressure from Greenpeace and other antibiotechnology organizations.”<sup>171</sup> “If we are going to produce enough food for our people,” wrote Kumar, “farmers must have access to the same tools as growers in the developed world.”<sup>172</sup>

Blanket opposition to GM foods makes little sense in a country like India, where 21% of the population does not get enough food every day, and 46% of children are underweight.<sup>173</sup> Moreover, India

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166. *Id.* at 33-34.

167. R. Ramachandran, *Global Spread*, FRONTLINE, Feb. 27-March 12, 2010, available at <http://www.frontlineonnet.com/fl2705/stories/20100312270502200.htm>.

168. *Id.*

169. Erika Kinetz, *A Hungry India Balks at Genetically Modified Crops*, US NEWS AND WORLD REPORT (Feb. 16, 2010), <http://www.usnews.com/science/articles/2010/02/16/india-balks-at-genetically-modified-crops>.

170. *Id.*

171. Rajesh Kumar, Op-Ed., *India's Genetically Modified Mistake*, WALL ST. J. (Feb. 11, 2010), <http://online.wsj.com/article/SB10001424052748704140104575057233227825988.html>.

172. *Id.*

173. Kinetz, *supra* note 169.

has been successfully growing GM cotton for the past nine years—a practice that “has spread quickly because it lowers input costs and increases productivity.”<sup>174</sup> But in the heated and extremely polarized debate surrounding GM technology in India, conflicting assertions abound. According to Dr. A.S. Anand, of Karnataka’s Organic Farming Mission, “Bt cotton hasn’t reduced the use of pesticides or chemicals and the yield is not better.”<sup>175</sup> Can both sides be right? A closer look at early Indian adopters of Bt cotton can help to illuminate this problem.

In 2003, a group of agricultural economists conducted an independent survey of Bt and non-Bt cotton growers in four Indian states,<sup>176</sup> following the end of India’s first official Bt cotton growing season.<sup>177</sup> The study found that, on average, input costs were significantly higher per acre for the Bt cotton growers (lower pesticide costs were outweighed by the high price of GM seed), but the Bt cotton’s higher yields resulted in a much higher net average profit: 5,294 rupees per acre, compared with only 3,133 rupees per acre for conventional cotton.<sup>178</sup>

Behind the averages, however, lay a great deal of regional variation, as one would expect for a large country with very diverse agricultural regions.<sup>179</sup> Most notably, while the Bt cotton growers in three states enjoyed significantly higher profits, those in Andhra Pradesh suffered losses compared with their non-Bt growing neighbors.<sup>180</sup> The study found two reasons for this. First, cotton growers in Andhra Pradesh spray their crop with pesticides more often than in the other regions, so they experience less yield benefit from Bt cotton’s pest resistance.<sup>181</sup> Second, Andhra Pradesh experienced a severe drought during the 2002-03 growing season.<sup>182</sup> None of the three varieties of Bt cotton available in 2002 was especially

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174. Kumar, *supra* note 171.

175. *India Divided Over Plans for GM Aubergine*, BBC NEWS (Feb. 9, 2010), [http://news.bbc.co.uk/2/hi/south\\_asia/8503825.stm](http://news.bbc.co.uk/2/hi/south_asia/8503825.stm).

176. Matin Qaim et al., *Adoption of Bt Cotton and Impact Variability: Insights from India*, 28 REV. AGRIC. ECON. 48, 50 (2006). The states covered were Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu. *Id.*

177. *Id.* at 49. The authors note that “unauthorized” Bt cotton seeds were being sold in Gujarat before 2002, and continue to be used today. Due to their low price, black-market GM seeds are so popular “that Bt cotton area in India might be double the officially registered total.” *Id.* at 56.

178. *Id.* at 51-52.

179. Qaim et al., *supra* note 176, at 52.

180. *Id.*

181. *Id.*

182. *Id.* at 52-55.



drought-tolerant, meaning that farmers in Andhra Pradesh who grew traditional drought-resistant strains had higher yields that year.<sup>183</sup>

One important lesson from this study is that switching to a GM crop variety can yield very different results in different agro-ecological regions—a phenomenon the study authors call “impact variability.”<sup>184</sup> Studies that emphasized findings from Andhra Pradesh in 2002-03 found ample evidence that Bt cotton was not good for Indian farmers,<sup>185</sup> while a two-year study in Maharashtra reported “[s]izeable farm-level economic gains” from adoption of Bt cotton.<sup>186</sup> Because of impact variability, farmers will benefit most from a GM crop when the new trait (such as the Bt gene) is added to a variety that is well-suited to their specific region. The beneficial effect of a new trait can be counteracted when the variety chosen for genetic modification is poorly adapted to local growing conditions, as happened in Andhra Pradesh.<sup>187</sup>

Another important lesson from the Indian study is that a high regulatory burden<sup>188</sup> placed on GM crops results in a significant lag time between the development of productive new hybrids and their availability in GM form. This was the case in India for the hybrid cotton seed known as “Bunny,” which was used by some of the conventional growers in the above survey, but did not become available in Bt form in India until 2005.<sup>189</sup> The increased productivity of this hybrid and its unavailability to Bt cotton growers significantly lowered the productivity differential between Bt and conventional cotton in the survey. When the economists controlled for this “Bunny effect” in the data, they found that the three-state (excluding Andhra Pradesh) average yield gains from Bt cotton increased from 42% to 59%.<sup>190</sup>

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183. *Id.* at 54-55.

184. Qaim et al., *supra* note 176, at 52, 54.

185. *Id.* at 52.

186. *Id.* at 49.

187. The authors refer to this as “germplasm effects.” *Id.* at 52-53.

188. Paarlberg notes that in India, “the approval of GM cotton was delayed for several years” in order to test the effects of feeding the product to goats, cows, water buffalo, poultry, and fish, as well as possible gene flow and soil issues. Regulators “were finally shamed into giving an official approval” only after farmers had already begun successfully growing Bt cotton illegally. PAARLBERG, *supra* note 122, at 120-21.

189. *Id.* at 55-56. The Bt Bunny cotton is known in India as “Sharma.”

190. *Id.* at 55. The four-state totals, even without controlling for the Bunny effect and the losses in Andhra Pradesh, showed an average yield increase of 27% for Bt cotton. *Id.* at 52.

The economists concluded from their survey that Indian farmers would benefit from a relaxed regulatory approval procedure for GM crops, instead of the current system in which each new variety of Bt cotton requires separate testing and approval.<sup>191</sup> This would cut the lag time between new hybrid development and GM versions, allowing for more locally adapted GM varieties.<sup>192</sup> Additionally, relaxed regulation is likely to lower the price of GM seed by increasing market competition.<sup>193</sup>

In 2008 alone, 1.2 million Indian farmers switched to Bt cotton, bringing the Bt share of India's total cotton-growing area up to nearly 74%.<sup>194</sup> Recent studies in Andhra Pradesh show that farmers there are now reaping the benefits of Bt cotton, with one study finding a 42% average increase in yields for farmers switching to Bt varieties.<sup>195</sup> In addition, pesticide use has continued to decline among Bt cotton growers, as farmers in the early years of adoption were apt to over-apply pesticides "out of anxiety."<sup>196</sup> According to a study by the University of Agricultural Sciences, Dharwad, "cultivation of Bt cotton considerably reduced the frequent health concerns of farmers, such as giddiness, nausea and itching caused by pesticide spraying in non-Bt cotton fields."<sup>197</sup>

Before issuing the Bt brinjal moratorium, Jairam Ramesh, the Environment Minister, decided to convene "a series of countrywide consultations" in order to assess the public's views on the matter.<sup>198</sup> But, as Indian journalist R. Ramachandran points out, such public consultation is most meaningful when the public is well-informed about the issue at hand.<sup>199</sup> In contrast, "[a]ny information that the [Indian] public has today is largely what is spread by activists and NGOs, right or wrong, with no attempt on the part of the Ministry to provide a scientifically sound perspective."<sup>200</sup>

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191. *Id.* at 56.

192. Qaim et al., *supra* note 176, at 56.

193. *Id.*

194. Ramachandran, *supra* note 167.

195. *Id.*

196. *Id.*

197. *Id.*

198. R. Ramachandran, *The GM Debate*, FRONTLINE, Feb. 27-Mar. 12, 2010, available at <http://www.frontline.in/stories/20100312270500400.htm>. Bt brinjal was officially approved by the Indian government's Genetic Engineering Approval Committee in October 2009, but could not be commercialized without approval from the Ministry of Environment. *Id.*

199. *Id.*

200. *Id.*

One of the Indian public's major concerns about the new Bt brinjal is that its Bt gene is owned by corporate super-villain Monsanto.<sup>201</sup> "It would not be an exaggeration," wrote Jairam Ramesh in his report, "to say that public concerns about Bt brinjal have been influenced very heavily by perceptions of Monsanto itself."<sup>202</sup> However, concerns about Monsanto have not slowed India's adoption of Bt cotton, which contains the very same Bt gene (Cry1Ac) as the Bt brinjal.<sup>203</sup> In the public confusion over Bt brinjal, Monsanto may be a convenient repository for vague, ill-defined anxieties, rather than an actual threat to Indian farmers. As Monsanto India's director, Gyanendra Shukla, points out, "[n]o one on this earth can sell any technology which does not deliver value to the farmer."<sup>204</sup>

Opposition to GM crops based on concerns about corporate ownership or monopoly, as with Monsanto's Bt gene, presents a stark contrast to opposition based on health or environmental concerns.<sup>205</sup> The latter position questions the value of the technology itself and favors strict regulation, while the former implies that GM technologies are "of such great potential benefit to society that access to them should not be legally restricted by patent owners."<sup>206</sup> If Indians are wary of Monsanto, for example, a rational stance would be to support increased funding for public agricultural research, along with a streamlined regulatory approach that cash-poor public institutions can afford to navigate. After all, there are hundreds of alternatives to Monsanto's Bt gene, some of which are owned by public organizations.<sup>207</sup> "We are looking forward for drought-resistant varieties—disease, pests, salinity," says P.G. Chengappa of Bangalore's University of Agricultural Sciences. "We need gene technology to combat these problems."<sup>208</sup>

### *B. Developing GM Crops for the Poor: Golden Rice and Food Politics*

Every year in the developing world, an estimated 250,000 to 500,000 children go blind, and one million children and adults die,

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201. Kinetz, *supra* note 169.

202. *Id.*

203. Ramachandran, *supra* note 167.

204. Kinetz, *supra* note 169.

205. Torrance, *supra* note 145, at 259.

206. *Id.* at 259-60.

207. Kinetz, *supra* note 169.

208. *Id.*

due to Vitamin A deficiency.<sup>209</sup> Many of these people rely on rice, whose edible endosperm contains no Vitamin A, for a substantial portion of their food calories.<sup>210</sup> In response to this problem, two biologists (with support from the Rockefeller Foundation) spearheaded the development of a type of GM rice that can produce beta-carotene, a dietary precursor to Vitamin A.<sup>211</sup> Dubbed “Golden Rice” for its rich yellow color, the new rice emerged from the lab in 1999, and American field trials began in 2004.<sup>212</sup>

In 2001, food writer Michael Pollan claimed in *The New York Times Magazine* that “an 11-year-old would have to eat 15 pounds of cooked golden rice a day—quite a bowlful—to satisfy his minimum daily requirement of vitamin A.”<sup>213</sup> Pollan’s article portrayed Golden Rice as a cynical ploy to coerce guilty developed-world citizens into accepting GM technology. To support this position, he quoted Gordon Conway, then-president of the Rockefeller Foundation, as saying that “[t]he public-relations uses of golden rice have gone too far,” and that the Foundation “do[es] not consider golden rice the solution to the vitamin-A deficiency problem.”<sup>214</sup>

While fifteen pounds of rice is indeed “quite a bowlful,” it is difficult to say where Pollan obtained this figure. It may have been directly from Greenpeace, who asserted in a 2001 press release that a grown woman would have to eat nine kilograms of cooked Golden Rice per day in order to obtain sufficient Vitamin A.<sup>215</sup> Or it may have been from Indian food activist Vandana Shiva, who claims that “an adult would have to consume 2 kg 272g of [golden] rice per day” to meet Vitamin A needs.<sup>216</sup> In a strange twist of logic, Shiva states that Golden Rice is actually “[a] technology for creating Vitamin A deficiency,” because “one family member would consume the entire family ration” of rice in an attempt to get enough Vitamin A.<sup>217</sup>

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209. Erin Baggott, *A Wealth Deferred - The Politics and Science of Golden Rice*, HARVARD INT’L REV., Fall 2006.

210. Torrance, *supra* note 145, at 268.

211. *Id.*

212. Baggott, *supra* note 209.

213. Michael Pollan, *The Great Yellow Hype*, N.Y. TIMES MAG., Mar. 4, 2001, available at <http://www.michaelpollan.com/article.php?id=15>.

214. *Id.*

215. GREENPEACE GENETIC ENG’G CAMPAIGN, GENETICALLY ENGINEERED PRO-VITAMIN A ‘GOLDEN RICE’: REALITY OR FICTION, (Feb. 2001), available at <http://archive.greenpeace.org/geneng/reports/food/GRice.pdf>.

216. Vandana Shiva, *The ‘Golden Rice’ Hoax: When Public Relations Replaces Science*, ONLINE.SFSU.EDU, <http://online.sfsu.edu/~rone/GEessays/goldenricehoax.html> (last visited Feb. 14, 2011).

217. *Id.*

Pollan's quotes from Gordon Conway are excerpted from a letter that Conway wrote to Greenpeace in response to the Shiva report.<sup>218</sup> However, Pollan completely misrepresents the positions of Conway and the Rockefeller Foundation. After stating that the Foundation doesn't consider Golden Rice "the solution to the vitamin A deficiency problem," Conway goes on to explain in the next sentence that the new rice merely "provides an excellent complement" to other solutions such as a balanced diet and nutritional supplements.<sup>219</sup> He also points out that many poor children do not have access to a diversity of foods, especially during the dry seasons, leading to an increased dependence on "cheap food staples such as rice."<sup>220</sup> Finally, Conway notes that Golden Rice is intended to help cure Vitamin A *deficiency*, not a total lack of Vitamin A, and that "the best Golden Rice lines reported in *Science* could contribute 15% - 20% of the daily requirements."<sup>221</sup>

In fact, by 2005, newer varieties of Golden Rice contained 23 times the amount of beta-carotene found in the original prototype.<sup>222</sup> By 2009, researchers showed that the latest version, called "Golden Rice-2," provided about 50-60% of an adult's Recommended Dietary Allowance for Vitamin A in a single eight-ounce serving.<sup>223</sup> However, the enhanced rice is still not available commercially, and is not expected to be until 2012 at the earliest.<sup>224</sup> Ingo Potrykus, one of the two inventors of Golden Rice, estimates that, had the new rice been developed through mutation breeding instead of genetic engineering, it would have been available in 2002.<sup>225</sup> The ten-year delay "is due to nothing else but routine, regulatory requirements," despite the fact that "no risk to the environment or to the consumer can be claimed even hypothetically."<sup>226</sup> This regulatory delay, adds Potrykus

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218. Letter from Gordon Conway, President, Rockefeller Found., to Doug Parr, Greenpeace (Jan. 22, 2001), available at [http://www.biotech-info.net/conway\\_greenpeace.pdf](http://www.biotech-info.net/conway_greenpeace.pdf).

219. *Id.*

220. *Id.*

221. *Id.*

222. Jorge E. Mayer, *The Golden Rice Controversy: Useless Science or Unfounded Criticism?* BIOSCIENCE, Sept. 2005, at 726.

223. Marcia Wood, *Golden Rice-2 Shines in Nutrition Study*, AGRIC. RES., May-June 2010, at 6.

224. Potrykus, *supra* note 163.

225. *Id.*

226. *Id.*

with a note of bitterness, “translates, on the basis of the calculated impact, to far more than 400,000 lives lost.”<sup>227</sup>

### *C. Agriculture in an Age of Climate Change*

The cycle of drought and poverty may be one of the reasons that Green Revolution technology has not taken hold in many parts of Africa. Inputs like fertilizer and high-yielding hybrid seeds cost money, which can then be lost if the rains do not come and the crops fail.<sup>228</sup> In Africa, 41% of all cultivated land is in hot, dry areas without irrigation, leaving farmers extremely vulnerable to variations in rainfall.<sup>229</sup> Before the creation of an effective food aid system, such regions were prone to devastating famines, such as those that killed over a million Africans in the 1980s.<sup>230</sup> Today, food aid can prevent starvation, but farmers whose crops fail are still susceptible to impoverishment, as they may have to borrow money, sell off assets, or forgo non-essentials like education until the crops return.<sup>231</sup>

While drought is already a worrisome problem for many of the world’s farmers, global climate change is set to make it much worse. Current estimates predict that, by the end of this century, “much of the world will be experiencing summers hotter than the hottest summer now on record.”<sup>232</sup> The effects of these severe temperature increases, already potentially disastrous for crop yields in much of the world, are likely to be exacerbated by glacier melt, which will decrease water availability during dry months and increase flooding during wet months.<sup>233</sup> Other changes may include increased soil salinity, as sea levels rise and coastal areas flood, as well as shifts in the geographical ranges of plant (and animal) pathogens.<sup>234</sup>

New crops that are genetically engineered to withstand dry conditions or saline soil could significantly stabilize crop yields for some developing countries. Monsanto has already begun field trials in the U.S. of its first drought-tolerant GM corn, which is expected to be

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227. *Id.*

228. PAARLBERG, *supra* note 122, at 157.

229. *Id.* at 153.

230. *People and Populations at Risk*, FAO.ORG, <http://www.fao.org/docrep/U8480E/U8480E05.htm> (last visited Feb. 14, 2011).

231. PAARLBERG, *supra* note 122, at 155.

232. N. V. Fedoroff et al., *Radically Rethinking Agriculture for the 21st Century*, SCIENCE, Feb. 12, 2010, at 833.

233. *Id.*

234. *Id.*

commercially available in 2012.<sup>235</sup> However, as observed in a WHO report on food biotechnology, “technologies tend to be developed in response to market pressures, and not to the needs of the poor who have no purchasing power.”<sup>236</sup> Many Africans, for example, will not eat yellow corn, considering it inferior to white corn and fit only for animal consumption.<sup>237</sup> For “a relatively modest cost,” the new drought-resistance traits could be transferred to African varieties of white corn, but, as with the improvement of landraces, there is often not enough profit potential to motivate private corporations to develop crops for the poor.<sup>238</sup> Researchers in developing countries are also working on drought tolerance—with pioneering work on drought-tolerant soybeans in South Africa, drought-tolerant wheat in Egypt, and drought- and salt-tolerant cowpeas in China—but strict and expensive regulatory requirements will pose a formidable barrier to commercialization.<sup>239</sup>

In order to make drought-tolerant white corn and other new crops available to poor subsistence farmers, effective partnerships are needed between public and private institutions.<sup>240</sup> One example of such a partnership is the Africa Biofortified Sorghum Project, a coalition of nine African and American institutions, public and private, working to develop nutritionally-enhanced sorghum.<sup>241</sup> Another example is the Humanitarian Golden Rice Network, through which the Syngenta corporation and various Asian and African rice-breeding institutes collaborate to create locally adapted versions of Golden Rice.<sup>242</sup> Large corporations are often willing to license their GM technologies for free in extremely poor countries, as there is no profit to be made anyway.<sup>243</sup> Ingo Potrykus, the father of Golden Rice, explains, “Delivery of public sector-based products requires collaboration with the private sector . . . Time and costs for delivery of a transgenic product to the market, as the consequence of regulation, are so immense that no public institution nor any small or me-

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235. Nigel Williams, *The Growing GM Challenge*, 19 CURRENT BIOLOGY R268 (Apr. 2009).

236. WORLD HEALTH ORG., *supra* note 158, at 35.

237. THOMSON, *supra* note 26, at 136.

238. PAARLBERG, *supra* note 122, at 163-64.

239. *Id.* at 161.

240. THOMSON, *supra* note 26, at 139-40; *see* Potrykus, *supra* note 163.

241. THOMSON, *supra* note 26, at 139.

242. *Id.* at 135-36.

243. PAARLBERG, *supra* note 122, at 115.

dium sized private enterprise can afford to invest the necessary personnel nor the funds.”<sup>244</sup>

## VI. CONCLUSION

In 1966, the International Covenant on Economic, Social, and Cultural Rights (ICESCR) recognized “the fundamental right of everyone to be free from hunger.”<sup>245</sup> Parties to the convention are required, “individually and through international co-operation,” to take the measures necessary “[t]o improve methods of production, conservation and distribution of food *by making full use of technical and scientific knowledge.*”<sup>246</sup> Yet, nearly three decades after the ICESCR entered into force, the WHO reported that international regulation of genetically modified organisms was still sector-based and uncoordinated, presenting major hurdles to developing countries trying to create effective regulatory frameworks for the use of biotechnology.<sup>247</sup> In addition to this evident lack of international co-operation, many developed countries (along with their NGOs) have actively worked to keep genetic engineering technology out of the hands of the countries who need it most.<sup>248</sup>

In 2009, the Royal Society released “the most comprehensive report on the future of British agriculture in a generation.”<sup>249</sup> The report tacitly acknowledged Britain’s responsibility under the ICESCR by calling on the British government to increase its spending on agricultural innovation, with the goal of leading the world in the development of new GM crops to feed a growing global population.<sup>250</sup> Greenpeace, predictably, objected to the report, calling GM crops a distraction from the goal of fighting poverty, and pointing out that the world already produces enough food for everyone, if only it were distributed more fairly.<sup>251</sup>

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244. Potrykus, *supra* note 163.

245. International Covenant on Economic, Social and Cultural Rights, G.A.Res. 2200 (XXI) A, U.N. GAOR, 21st Sess. Supp. No. 16, UN Doc. A/6316, at art. 11 (Dec. 16, 1966), available at <http://www2.ohchr.org/english/law/pdf/cescr.pdf>.

246. *Id.* (emphasis added)

247. See WORLD HEALTH ORG., *supra* note 158, at iv.

248. PAARLBERG, *supra* note 122 *passim*.

249. Louise Gray, *GM Crops Must be Grown in Britain, Royal Society Says*, TELEGRAPH (Oct. 21, 2009), <http://www.telegraph.co.uk/earth/earthnews/6387540/GM-crops-must-be-grown-in-Britain-Royal-Society-says.html>.

250. *Id.*

251. Gerard Wynn, *World Must Use GM Crops, Says UK Science Academy*, REUTERS, Oct. 21, 2009, available at <http://www.reuters.com/article/idUSTRE59K0AT>



The “food distribution, not technology” argument is an old one, and deeply flawed for two reasons. First, while it may be true that a more equitable global food system would go a long way toward feeding the world’s hungry, such a system does not appear to be immediately forthcoming, and obstructing GM technology is unlikely to bring it forth any faster.<sup>252</sup> Second, the world’s population is still growing, as are global income levels. As incomes rise, so does consumption of meat, dairy, and poultry, placing even greater demands on grain and soybean supplies.<sup>253</sup> According to the UN’s Food and Agriculture Organization, global food production will have to increase by 70% in order to feed the additional 2.3 billion people expected to join the world population by 2050.<sup>254</sup> A full range of technologies and practices will be needed to meet this challenge without jeopardizing the planet’s already fragile environment.

The Royal Society joins a growing list of scientists and organizations calling for a “doubly green revolution” (to use Gordon Conway’s felicitous phrase)—one that would update the technological innovations of the original Green Revolution while working to minimize agriculture’s negative impacts on the environment. No one is claiming that GM crops are a panacea for world hunger, but they can be “an extremely important part of the solution,”<sup>255</sup> along with conventional crop breeding, soil management techniques, and improved rural infrastructure and education. While no technology is without risk, advocates of applying the precautionary principle to GM crops should consider the risks of over-regulation against the risks of the technology itself. “Can we be absolutely sure,” asks one South African activist, “that rejecting biotechnology will not cause future poverty, hunger and malnutrition in Africa?”<sup>256</sup> The putative dangers of genetic engineering—superweeds, new allergens, toxic foods—have proven to be minimal and manageable. The dangers of hunger and poverty, on the other hand, are tremendous and very

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20091021 (The article quotes Marco Contiero, the European GM policy director for Greenpeace quoted in note 2, *supra*).

252. See THOMSON, *supra* note 26, at 131 (noting that political conflicts, weak infrastructure, distribution costs, and different cultural food preferences all present barriers to improved global food distribution).

253. *Id.*; see also MANNING, *supra* note 35, at 7 (noting that “[i]t takes about seven grams of grain to make a gram of beef”).

254. FOOD AND AGRIC. ORG., HOW TO FEED THE WORLD IN 2050 5, 8 (2009), available at [http://www.fao.org/fileadmin/templates/wsfs/docs/expert\\_paper/How\\_to\\_Feed\\_the\\_World\\_in\\_2050.pdf](http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf).

255. THOMSON, *supra* note 26, at 140.

256. Nolutshungu, *supra* note 162.

real, and dealing with them will require all of the creativity, technology, and dedication the world can muster.

