SCIENCE AND SOCIETY

Opposition to transgenic technologies: ideology, interests and collective action frames

Ronald J. Herring

Abstract | Genetic engineering has enabled significant, accepted innovations in medicine and other fields. In agriculture, however, a global cognitive divide around 'genetically modified organisms' (GMOs) has limited the diffusion and scope of this technology. The framing of agricultural products of recombinant DNA technology as GMOs lacks biological coherence, but has proved to be a powerful frame for opposition. Disaggregating the concept of the 'GMO' is a necessary condition for confronting misconceptions that constrain the use of biotechnology in addressing imperatives of development and escalating challenges from nature, especially in less-industrialized nations.

Despite globally organized opposition, few innovations in agriculture have spread so rapidly as transgenic crops. Still, much remains to be done — particularly the expansion of disease-resistant varieties, increased yields, biofortification of food for poor consumers, substitution of plant-produced targeted endotoxins for broad-band pesticides and, perhaps most crucially, drought-resistant and salt-resistant cultivars. The imperative to develop more versatile and resilient crops for vulnerable farmers and nations is aggravated by the twin global challenges of climate change and ensuring the sustainability of agriculture. The precision, flexibility and speed of genetic engineering in comparison with alternatives become vital when time and resources are short. There is now considerable evidence that this technological potential is real for the most precarious agroecologies and poorest rural people[1–6].

Slow progress towards these urgent goals is explained in part by the interests of commercial firms: as with pharmaceuticals, poor people in poor places with difficult bureaucracies might produce thin profits. Likewise, the thicket of intellectual property claims might slow diffusion of technological innovation[7]. However, obstacles posed by political opposition have been more powerful than either of these constraints. Relatively small numbers of people with no direct agricultural interests have had a disproportionately large influence relative to the large numbers of people with urgent interests[8]. Nevertheless, crop biotechnology has spread rapidly, to more countries, more hectares and more farmers, altering the configuration of political interests globally. Conceptually, we are approaching a tipping point in relation to the global acceptability of transgenic crops in terms of trade; it is unclear which way the balance will tip. With pharmaceuticals, the tipping point came early: recombinant DNA (rDNA) technology was accepted globally; there are no 'Frankenpills' on posters. Responses to genetic engineering in plant breeding have been fundamentally different. Framed as 'genetically modified organisms' (GMOs), transgenic crops have encountered a restructuring of global trade. With this segregation of agricultural markets has come a new matrix of interests of both farmers and nation states. Few framings have been so consequential.

Much of the current public discourse on genetic engineering targets 'Luddism' or 'anti-science' as obstacles to taking more advantage of the genomics revolution. However, this view fails to appreciate the complex network of interests and ideas surrounding genetic engineering. After outlining global patterns of diffusion of agricultural biotechnology, this article explores the reasons for, and the results of, successful opposition. It concludes with implications for future applications of the genomics revolution in biology, particularly in the less industrialized world.

Diffusion of agricultural biotechnology

In the most recent data, for 2007, 23 countries have officially-approved transgenic crops growing in fields. Despite the political rhetoric of north versus south, more than half of these countries do not fall into the category of 'high-income economies'. In descending order of acreage these are: the United States, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, the Philippines, Australia, Spain, Mexico, Colombia, Chile, France, Honduras, the Czech Republic, Portugal, Germany, Slovakia, Romania and Poland. Of political importance for the future of biotechnology is the presence of eight European Union (EU) countries in this group, led by Spain in terms of acreage. Nevertheless, European acreages are small and remain contentious. For example, in January 2008, France unilaterally banned MON810 transgenic maize. Spain immediately objected to this decision, appealing to decisions of the European Food Safety Authority (EFSA) to uphold its position[9]; French maize growers likewise objected, appealing to their own interests[10].

Global acreage and the number of nations officially allowing cultivation of transgenic crops are presented in FIG. 1. One must emphasize the caveat 'officially'; in these data, which are from the International Service for the Acquisition of Agri-biotech Applications (ISAAA), and in all institutional data, unauthorized plantings of transgenic crops are not represented. The extent of these plantings is unknown, but available evidence suggests that it is quite large[11]. The AGBIOS comprehensive database on transgenic crops does not list, for example, Thailand, Pakistan or Vietnam, yet transgenic crops are widely grown in these countries (R.J.H., unpublished observations). When transgenic seeds in low-income countries have proved too expensive or too highly regulated for acquisition, farmers have often acquired illicit 'gray market' seeds — also known as brown bag, Creolized or stealth seeds. Farmers have used illegal seeds smuggled across boundaries, have saved transgenic seeds for replanting, or have bred their own from legal or illegal stock[11–14]. This type of farmer agency parallels the broader global underground economy that flies under the radar of seemingly authoritative international institutions enforcing property and safety norms[15].

One lesson from global distribution data is that market-driven steering of research and development might bypass crucial rural needs. Transgenic acreage is still dominated by two traits that cut farmers' costs — insect resistance and herbicide tolerance — and the major crops are still soy, cotton, maize and canola. By far the most rapid growth in terms of traits is herbicide resistance, as FIG. 2 demonstrates. If technology is to anticipate a more volatile climate with a higher number of poor farmers, more stressful growing conditions and declining land per capita, social innovation in steering mechanisms to drive new priorities in research and development is imperative[16,17].

Despite limitations on cultivars and traits, transgenic crops have been accepted by farmers with alacrity, when affordable and available, although access is still limited by politics in many places — some of them the poorest on earth. Farmers have experimented with transgenics, adopted them when their traits have proved useful, and have often acquired the technology even at the risk of prosecution. Opposition to transgenics has come not from farmers, by and large, but from those with much less direct interests in agriculture.

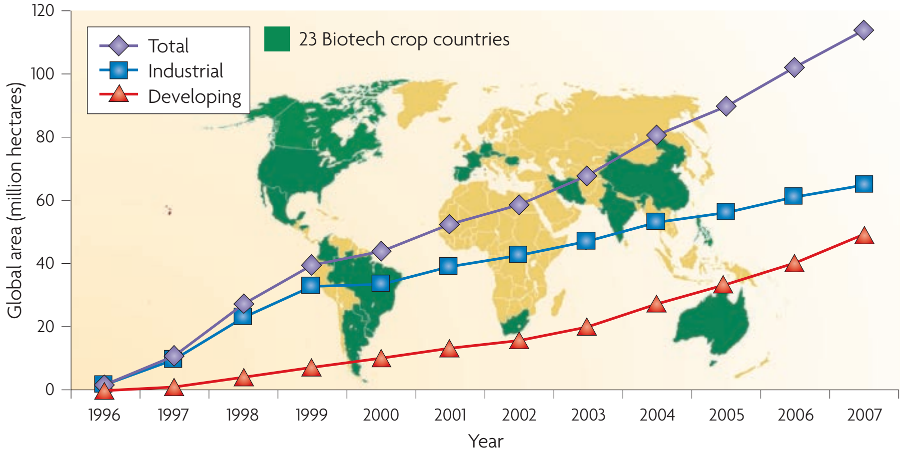

Figure 1 | **Global distribution of transgenic crop production, 1996–2007.** Data for this figure is taken from REF. 82.

Framing GMOs: ideas and interests

Opposition to agricultural biotechnology has been led by international non-governmental organizations (INGOs) — for example, Greenpeace International — or less substantial but effective transnational advocacy networks. Both ideas about the relevant technologies and the interests of various activists have been engaged in this opposition, and are intricately intertwined.

Some interests are straightforward: profits for commercial firms, incomes for farmers, and jobs and resources for INGOs and their local affiliates. However, for the mass public to understand their own interests in genetic engineering requires processing through a cognitive screen that makes sense of the structure around us. Social-movement theorists call this cognitive screen a 'collective action frame'[18–21]. Frames typically contain elements that are diagnostic (identifying problems and causation), prognostic (allocating blame) and motivational (providing reasons for action). Mobilization of global coalitions requires both shared collective action frames and a mode of diffusion[22,23]. Social scientists attribute considerable, although variable, explanatory power to such framing when analysing the success or failure of collective action[24].

Science continually presents new challenges to the way interests are framed by citizens, officials and politicians[25]. The discovery and redefinitions of interests in ozone holes and climate change were driven by increasingly authoritative atmospheric science. Interests in biotechnology must also pass through a cognitive screen; the science is difficult to grasp, uncertainties remain, and understanding is unevenly distributed within and across political formations. The most general frames have posited either novel threats or technological promise arising from rDNA techniques[26,27].

The power of framing is evident from the behaviour of global protagonists. For example, the Pesticide Action Network International (PAN) mobilizes support for reductions in pesticide use. PAN has two overriding interests: sustainability and funding itself. Bt technology in crops theoretically reduces pesticide applications by enabling plants to express *Bacillus thuringiensis* (Bt) protoxins in their tissues, which confers a level of insect resistance[28]. Before there was systematic evidence on results in cropping systems, Bt crops were opposed in coalitions of which PAN is a part. Even field trials to determine environmental effects were opposed, and sometimes destroyed[29,30]. Because introduction of the insect-resistant trait into plants involved genetic engineering, the plants were stigmatized. The trait itself — insect resistance — was compatible with a frame of sustainability, as it enables reduced pesticide use[31]. Framed as GMOs, Bt plants were consigned to an incompatible frame. Mobilization against modern biotechnology presupposes this decisive framing: one technique for modifying plants is unacceptable, whatever the usefulness of the cultivar to the farmer or environment.

Social framing of transgenic crops as 'unnatural' and 'anti-developmental' has obscured variations that matter biologically. Regardless of trait, genetic event or cultivar, all products of agricultural rDNA technology have been lumped together in one ominous category: GMOs. GMOs in turn were framed as incompatible with other plausible frames — sustainability and development. The diagnostic element of this frame identified special dangers from novel organisms: the biosafety problem. Prognostic framing put bioproperty at odds with the science of assessing the safety of new technologies: potential threats could not be authoritatively evaluated because multinational corporations had strong proprietary interests in the results of trials. Because testing was done under corporate auspices, the science could not be trusted. Furthermore, bioproperty would permit multinational firms to control the world food supply, and to dominate and exploit farmers through patents and, most alarmingly, 'terminator technology' — gene use restriction technology (GURT) — that, in theory, renders transgenic plants sterile[32]. The motivational frame follows logically: caring for personal safety, for powerless victims of exploitation in the third world and for ecological integrity all necessitate opposition to GMOs, perhaps even militancy.

This remarkable framing has been generative, providing targets, locations and tactics that are crucial for activists in opposition to transgenic technologies. There are campaigns against 'GM food', celebration and promotion of 'GMO-free zones', and torching of GMO test plots. The frame has become embedded in regulatory strictures that apply exclusively to transgenic crops, delaying research and development[33,34]. The global biosafety provisions of the Cartagena Protocol — the rules set out under the Convention on Biological Diversity — set norms for dealing with 'living modified organisms', defined as transgenic seeds[35]. The radical cognitive move that created this generative frame was the separation of products of one form of genetic modification — rDNA technology — as a unique and novel category that is fundamentally different from those framed, by default, as natural. The question typically elided is: What is a GMO? The operative definition is provided by Article 2(2) of EU Directive 2001/18/EC5 (REF. 36): "'GMO' means an organism, with the exception of human beings, in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination." The bright line is constituted by the criterion "does not occur naturally by mating". By the mid-twentieth century, before rDNA technology, techniques far removed from mating or natural recombination came into plant breeding — for example, mutagenesis using radiation or chemicals, induced polyploidy, protoplast fusion and wide crosses of plants that do not normally sexually reproduce. Modern plant breeding techniques for genetic modification originated before rDNA technology[27,32,37,38].

Determining what is possible from natural recombination requires either great hubris or a creationist ontology. To take the example of Bt plants, transfer of genes from prokaryotic to eukaryotic species is by no means unheard of in nature[39]. Uncertainty about the outcomes of plant breeding is not confined to transgenics. Batista *et al.*[40] concluded that "improvement of a plant variety through the acquisition of a new desired trait, using either mutagenesis or transgenesis, may cause stress and thus lead to an altered expression of untargeted genes. In all of the cases studied, the observed alteration was more extensive in mutagenized than in transgenic plants." All plant breeding yields risks, but biosafety regulations apply only to transgenics.

Framing molecular breeding as the only meaningful form of genetic modification had political consequences. There was nothing inevitable or conspiratorial about this outcome. The regulatory regime in Europe reflected interactions among firms, industries, public perceptions of risk and institutions of governance in a specific historical conjuncture[41–43]. Nevertheless, the authoritative cementing of the GMO in Europe created opportunities for collective action, and, through the Cartagena Protocol and transnational activist networks, nodes for mobilization across national boundaries[27,44,45].

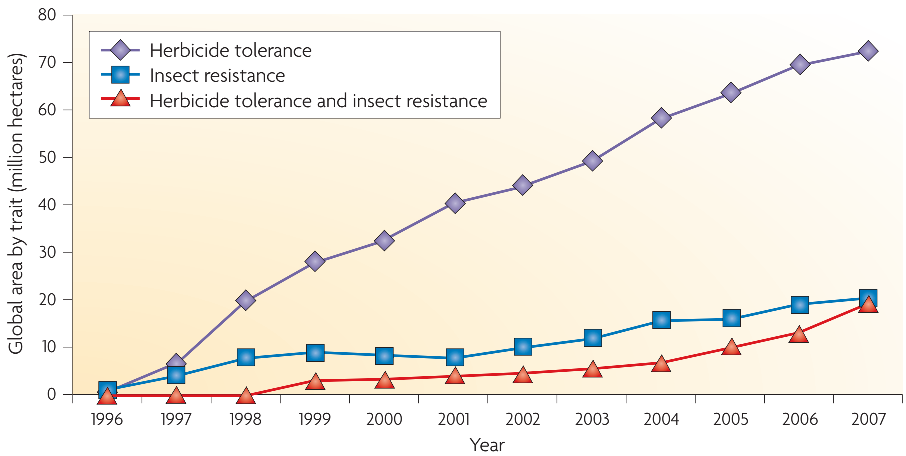

Figure 2 | **Global transgenic crop production by trait, 1996–2007.** Data for this figure is taken from REF. 82.

Disaggregating opposition

Although a European framing of GM food has contributed to global opposition to transgenics, Europeans themselves exhibit the same dominance of interests over ideology that one sees among farmers growing 'stealth seeds'[11]. Europeans — especially young Europeans — are no more suspicious of biotechnology generally than are Americans and Canadians (TABLES 1,2), but GM food remains suspect. This is a matter of interests, of usefulness. GM food generally has no perceived benefits but is seen to have some potential risk. Nevertheless, of the possible consumer benefits recognized in Eurobarometer surveys, three reasons for buying GM foods are all plausibly related to interests: less pesticide residue, nutritional benefits and general environmental protection[46]. These are all plausible or demonstrable benefits of molecular plant breeding.

Interests of European citizens in biotechnology other than that relating to food are generally recognized. The so-called white biotechnologies (industrial), like the red biotechnology (medical) applications, are widely supported. There is broad support for industrial applications in biodegradable plastics, bio-fuels and biopharming. More than 70% of respondents in the Eurobarometer 2005 study supported incentives to develop bio-fuels and bioplastics. European consumers even expressed willingness to pay more for them[46]. Even the highly controversial pharming, whereby pharmaceutical products with mammalian activity are produced by genetically engineered plants, received support from a larger number of people than those that opposed it, except in Austria.

Opposition activists understood this bifurcation of interests between food and other applications. It was not in their interest to mobilize opposition against drugs that involve rDNA technology. Global trade has not been segregated around GM drugs, although the use of rDNA technology is common in pharmaceuticals, and indeed much supported by public opinion in Europe[46]. Physicians are, for reasons of cognitive consonance, treated as authoritative: you have to believe your doctor to submit to treatment. By contrast, authoritative conclusions concerning food are contested. The US Food and Drug Administration (FDA) has ruled that foods from transgenic crops are "substantially equivalent" to foods produced by plants modified through other techniques[47]. This view might be incorrect, but it is an authoritative interpretation of the absence of difference (by gross measurement) between transgenic

Table 1 | **Optimism concerning new technologies**

	Do you think each of the following technologies will improve our way of life in the next 20 years?		
	% Europe	% United States	% Canada
Computers and IT	82	86	83
Biotechnology	75	78	75
Nanotechnology	70	71	68
Nuclear energy	37	59	46

This table was generated using data from REF. 46.

cultivars and their isogenic equivalents. Are foods from transgenic crops "substantially equivalent" to other sources, or sufficiently different to warrant extra caution, special labelling and a separate regulatory schema? The official European conclusion introduced caution into the calculation of interests by all consumers, and by food-exporting farmers and nations, just as the US FDA conclusion has largely normalized food from transgenic crops in the United States.

Once framed in terms of unique biosafety and bioproperty threats, GMOs became the object of pre-existing coalitions opposing corporate control and irresponsibility in the 1990s, drawing together American and European activists[48,49]. Europe was profoundly affected by this mobilization; over a few short years in the late 1990s broad support for biotechnology turned into intense opposition[46]. In France, for example, both the state and farmers originally framed biotechnology as essential for maintaining economic competitiveness; erosion set in with reframing of transgenics in terms of ecological risks, corporate power and threats to culturally validated norms for food[43,46,50]. Activists drew parallels with discharges of 'dangerous things' that concerned mass publics: Chernobyl, Three Mile Island, Love Canal, Bhopal. The idea of genes escaping into the environment — transgenic plants are 'released', other seeds are just planted — resonated with a discourse of corporate irresponsibility and environmental risk. The 'mad cow' outbreak and other disasters reinforced the notion that neither governments nor their authoritative science could be relied upon to protect the mass public, especially when corporate profits were at stake[51].

Metropolitan elites in low-income countries adopted European framing through international networks opposing globalization[30,52–55]. Complementarities of interests are apparent. INGOs needed authentic voices and faces of the 'third world' for their mobilization and funding, local activists needed resources[52]. INGOs then became dependent on their local brokers for information, putting a premium on reports of extreme events that attract media attention and spread through internet connections. For example, Vandana Shiva claimed that Bt cotton seeds were "genocidal", leading to the suicides of tens of thousands of Indian farmers[56,57]. Bt cotton leaves were reported to be responsible for deaths of sheep, then cattle, in villages of Andhra Pradesh, India. Such reports motivate activist opposition around the world, independently of their verifiability. The suicide claim defied the evidence on the economic usefulness of Bt cotton to farmers in India; the animal poisoning claim does not make sense in light of the mechanism for the lethal effect of the Bt protoxin Cry1Ac on lepidopterans, which cannot function in mammalian guts[4,28,31,58–61]. The validity of extreme claims 'from below' is hard to authenticate; the powerful cognitive screen of biosafety and risk surrounding GMOs eases the acceptance of extreme scenarios, however implausible.

GMOs and developmental interests

GMOs created dilemmas for low-income nations devising strategies for development[62]. With adverse regulation in Europe in the late 1990s, GM food — however biologically meaningless and impractical as a regulatory object[63] — became a distinct category for global trade and market segregation. Before this emergent segmentation had solidified, genetic engineering had widely engaged developmental interests. For example, announcements of projects such as Malaysia's 'biovalley' and Indonesia's 'bioisland' indicated strong interests of Asian states in biotechnology as a growth sector. Government officials involved in these projects explicitly worried about falling behind a 'new breed of super crops' and about 'biotech colonization' by China[64].

China, India and Brazil have the capacity and size to pursue biotechnology autonomously[65,66], but smaller and more dependent states became cautious. The structural power of European markets and European aid programmes, and the dependency effects of colonial ties — reinvigorated by INGOs — proved powerful retardants. This is especially true for Africa, where agriculture is in most desperate need of new technologies[8]. The success of anti-GMO opposition in framing as threatening some products of rDNA technology but not others and some forms of moving DNA around plants but not others effectively restructured developmental interests. To protect their nation's exports from the GM stigma, governments are reluctant to acknowledge that their farmers are growing unauthorized transgenic crops — thus producing part of the lag of official data behind actual patterns of adoption.

Although the international coalition against GMOs had common interests with their local partners in opposition to corporate globalization, their specific framing of biotechnology proved incompatible with local conditions. GMOs as creatures of multinational corporations with hegemonic intentions — biopiracy and monopoly — resonated with deep memories of colonial control and acute realization of inferior position in a hierarchical global economy[53,55,67]. But the power of this narrative proved weak on the ground. Mobilization against Bt cotton in India by Operation Cremate Monsanto, for example, completely failed. The interests and field experience of Indian farmers proved impervious to charges from activists of suicidal or genocidal seeds[4,12,56,57,59,61,62,68,69]. The fate of this campaign reflected the archetypal deep disjuncture between the ideas and interests of global activists and the farmers they claim to represent[8].

Table 2 | **Approval of genetically modified food and nanotechnology**

	% Europe	% United States	% Canada
Genetically modified food	45	61	53
Nanotechnology	76	81	81

This table was generated using data from REF. 46.

Likewise, positing a tyranny of monopoly and patent control proved inconsistent with the ingenuity of farmers and institutional capacity in countries with large agricultural populations. Intellectual property in seeds has proved difficult to claim or enforce. In the fields there is opportunistic appropriation of useful technology, similar to that rendering intellectual property rights ineffectual on films, pharmaceuticals, music and software[11]. Moreover, new institutional arrangements have arisen in response to bioproperty[32]. Humanitarian-use transfers loosen the property nexus for low-income farmers and countries[70]. Globally, the sphere of open-source technology has grown; in some countries, public-sector firms have been active in biotechnology[71], and universities have produced important breakthroughs — for example, the transgenic virus-resistant papaya produced by Cornell University and the University of Hawaii, USA[72,73]. Finally, even though such traits as Bt insect resistance were created to increase profits, seed technology is almost perfectly divisible; even the smallest farmer — or especially the smallest farmer — benefits from cheaper and more effective pest resistance[74].

Global opposition framed transgenics as hideously unnatural through the evocation of terminator technology[75–77]. GURT provided opponents with perhaps their most powerful dramaturgical tool. This prospective framing, however, outran the technology; to date, there is no parallel in commercialized seeds to the copyright protection built into DVDs, music and software. Ironically, GURT offers a biological solution to the environmental uncertainties introduced by gene flow[28], whereas social institutions have proved leaky[78]. Although often ineffective and costly, biosafety institutions have constituted nodes for mobilization as well as choke points for opponents of genetic engineering. Difficulties in creating these institutions slow the adoption of biotechnology and direct the interests of firms towards other sectors and places[34,44].

It is unclear how the global balance of forces on biotechnology will tip, but there is serious risk to the poorest farmers. Agriculture will almost certainly be stressed by climate change beyond anything seen historically. The poorest farmers have the least capacity to adjust. The worst case scenario would be a transgenics divide similar to the digital divide: technology lowers the costs of production for those with access, but leaves those without access at an even worse competitive disadvantage[74]. But the weight of evidence suggests that the powerfully generative frame of GMO may well prove to be as ephemeral as it has been conjunctural.

Breaking the frame

Global activism against genetic engineering in agriculture has slowed innovation and diffusion of technologies, but for reasons that do not predict future constraints. It seems entirely possible that the GMO frame will subside over time into the realm of niche politics — similar to opposition to vaccines or pasteurization — or to the realm of discretionary food preferences among well-fed people. First, it is the ideational construction of GM food that has been effective politically. Biomedical applications manifestly promote the interest of consumers; there are no campaigns for pharmaceutical-free zones. Second, successful opposition has been in formal-legal institutions, not in the fields of farmers, where direct interests have outweighed ideology. More and more farmers, in countries rich and poor, have material interests in biotechnology (FIG. 1); they have proved ready to lobby for transgenic crops or grow them without authorization if necessary, even when facing considerable risk. Third, rising international powers such as China, India and Brazil invest in biotechnology as a growth sector. Because there are competitive advantages in molecular breeding, national interests are likely to push against the international formal-legal restrictions on transgenic crops. Finally, we might anticipate that urgent crises will, over time, drive more interest in such fields as bioremediation, biodegradable plastics, drought-resistant plants[79] and biofortification of food for those who cannot afford dietary discretion[2].

The Nuffield Council in the United Kingdom rightly stressed the ethical obligation to use emergent technologies to alleviate human suffering wherever possible[80]. This obligation falls particularly on those privileged by accident of birth[81]. If aid programmes and INGOs from the wealthy world are to press their preferences in low-income countries, they have an obligation to get the empirics right, particularly when information about places remote from their experience is filtered through frames that rely on brokers with strong interests. Conscientious citizens of the 'first world' must understand that our political preferences have powerful influences on decisions in parts of the world where the options are fewer and less attractive. Would PAN be so opposed to GMOs if the evidence on pesticide reduction through Bt technology were widely understood? How can the frame incompatibility between a trait — insect resistance — and the stigma of GMO be maintained if the real, and urgent, interest is sustainability? How plausible are reports that year after year farmers in India plant seeds that fail them and destroy their environments? Had mobilizers against agricultural biotechnology had more respect for the rationality and agency of farmers in poor places, they might well have avoided egregiously erroneous constructions of their interests.

The first step forward, then, is to split up the concept of GMO, to think of it as the product of a particular juncture in history. That juncture combined real concerns of unknown risks of new technology and demonstrably faulty state regulation. But the science has moved on. Vital questions about crops and interests for the future involve more splitting and less lumping: what traits, what cultivars, which genetic events, where and under what conditions for what developmental purposes? Only with this knowledge can we devise priorities and steering mechanisms as aspirational and precise as the potentials of the technology.

Ronald J. Herring is at the Department of Government, Cornell University, White Hall 313, Ithaca, New York 14853, USA.
e-mail: rjh5@cornell.edu

doi:10.1038/nrg2338

1. Herring, R. J. (ed.) *Transgenics and the Poor: Biotechnology in Development Studies* (Routledge, Oxford, 2007).
2. Bouis, H. The potential of genetically modified food crops to improve human nutrition in developing countries. *J. Dev. Stud.* **43**, 79–96 (2007).
3. Zilberman, D., Ameden, H. & Qaim, M. The impact of agricultural biotechnology on yields, risks, and biodiversity in low-income countries. *J. Dev. Stud.* **43**, 63–78 (2007).
4. Narayanamoorthy, A. & Kalamkar, S. S. Is Bt cotton cultivation economically viable for Indian farmers? An empirical analysis. *Econ. Polit. Wkly* **41**, 2716–2724 (2006).
5. Persley, G. J. & Lantin, M. M. (eds) *Agricultural Biotechnology and the Poor: Proceedings of an International Conference, Washington, D. C., 21–22 October 1999* (Consultative Group on International Agricultural Research, Washington, 2000).
6. Horsch, R. B. & Fraley, R. T. in *Protection of Global Biodiversity: Converging Strategies* (eds Guruswamy L. D. & McNeely, J. A.) 180–189 (Duke Univ. Press, Durham, North Carolina,1998).
7. Murray, F. & Stern, S. in *Innovation Policy and the Economy* Vol. 7 Ch. 2 (eds Jaffe, A. B., Lerner, J. & Stern, S.) 32–69 (MIT Press, Cambridge, Massachusetts, 2006)
8. Paarlberg, R. L. *Starved for Science: How Biotechnology is Being Kept Out of Africa* (Harvard Univ. Press, Cambridge, Massachusetts, 2008).
9. [No author listed], España rechaza la cláusula de salvaguarda de Francia al maíz transgénico, *Besanda Portal Agrario* [online], <http://www.portalbesana.es/jsp/lstNoticias.jsp?ch=4&ca=21&cu=1&cd=22548> (2008) (in Spanish).
10. Nick Antonovics, N. & Fichot, N. (ed. Channing, R.) French govt move to ban Monsanto GMO draws fire *Reuters UK* [online], <http://uk.reuters.com/article/environmentNews/idUKPAB00373820080113> (2008).

11. Herring, R. J. Stealth seeds: biosafety, bioproperty, biopolitics. *J. Dev. Stud.* **43**, 130–157 (2007).
12. Devparna, R., Herring, R. J. & Geisler, C. C. Naturalizing transgenics: loose seeds, official seeds, and risk in the decision matrix of Gujarati cotton farmers. *J. Dev. Stud.* **43**, 158–176 (2007).
13. Jayaraman, K. S. India produces homegrown GM cotton. *Nature Biotechnol.* **22**, 255–256 (2004).
14. Gupta, A. K. & Chandak, V. Agricultural biotechnology in India: ethics, business and politics. *Int. J. Biotechnol.* **7**, 212–227 (2005).
15. Naim, M. *Illicit: How Smugglers, Traffickers and Copycats are Hijacking the Global Economy* (Doubleday, New York, 2005).
16. Borlaug, N. E. Challenges facing Crop Scientists in the 21st Century**.** American Society of Agronomy Annual Meeting November 3–5, 2007 New Orleans, Louisiana. *ASC meetings* [online], <https://www.acsmeetings.org/shared/files/borlaug-2007.pdf> (2007).
17. Conway, G. *The Doubly Green Revolution: Food for All in the Twenty-First Century* (Cornell Univ. Press, Ithaca, New York, 1999).
18. Snow, D. & Benford, R. D. in *Frontiers in Social Movement Theory* Ch. 6 (eds Morris, A. D. & Carol McClurg Mueller, C.) (Yale Univ. Press, New Haven & London, 1992).
19. Snow, D. & Benford, R. D. Framing processes and social movements: an overview and assessment. *Annu. Rev. Sociol.* **26**, 611–639 (2000).
20. Tarrow, S. 1992. in *Frontiers in Social Movement Research* (eds Morris, A. & Mueller, C.) (Yale Univ. Press, New Haven, Connecticut, 1992).
21. Snow, D. A. in *The Blackwell Companion to Social Movements* (eds Snow, D. A., Soule, S. A & Kreisi, H.) 380–413 (Blackwell Publishing, Oxford, 2004).
22. della Porta, D. & Kriesi, H. in *Social Movements in a Globalizing World* (eds della Porta, D., Kriesi, H. & Rucht, D.) 3–23 (St. Martin's, New York, 1999).
23. Tarrow, S. *The New Transnational Activism* (Cambridge Univ. Press, New York, 2005).
24. Snow, D. A., Soule, S. A. & Kriesi, H. (eds) *The Blackwell Companion to Social Movements* (Blackwell Publishing, Oxford, 2004).
25. Herring, R. J. in *Sage Handbook on Environment and Society* (eds Pretty, J. *et al.*) 299–313 (Sage Publications, London, 2007).
26. McHughen, A. *Pandora's Picnic Basket: The Potential and Hazards of Genetically Modified Foods* (Oxford Univ. Press, Oxford, 2000).
27. Winston, M. L. *Travels in the Genetically Modified Zone* (Harvard Univ. Press, Cambridge, Massachusetts, 2002).
28. Thies, J. E. & Devare, M. H. An ecological assessment of transgenic crops. *J. Dev. Stud.* **43**, 97–129 (2007).
29. Boal, I. A. in *Violent Environments* (eds Lee Peluso, N. & Watts, M.) 155–185 (Cornell Univ. Press, Ithaca, New York, 2001).
30. Shiva, V., Emani, A. & Jafri, A. H. Globalization and threat to seed security *Econ. Polit. Wkly* **34**, 601–613 (1999).
31. Shelton, A. M. Considerations on the use of transgenic crops for insect control *J. Dev. Stud.* **43**, 890–900 (2007).
32. Herring, R. J. The genomics revolution and development studies: science, politics and poverty. *J. Dev. Stud.* **43**, 1–30 (2007).
33. Paarlberg, R. L. *The Politics of Precaution: Genetically Modified Crops in Developing Countries* (Johns Hopkins Univ. Press, Baltimore, 2001).
34. Pray, C. E. & Naseem, A. Supplying crop biotechnology to the poor: opportunities and constraints. *J. Dev. Stud.* **43**, 192–217 (2007).
35. [No author listed], Genetic Use Restriction Technologies (GURTs) *Convention on Biological Diversity* [online], <http://www.cbd.int/programmes/areas/agro/gurts.aspx> (2006).
36. The European Parliament and The Council. *Off. J. Eur. Commun.* **L106**, 1–38 (2001).
37. Miller, H. I. & Conko, G. The Science of Biotechnology Meets the Politics of Global Regulation. *Issues in Science and Technology* [online], <http://www.issues.org/17.1/miller.htm> (2000).
38. Fujii, M., Andoh, C & Ishihara, S. Drought resistance of NERICA (New Rice for Africa) compared with *Oryza sativa* L. and millet evaluated by stomatal conductance and soil water content. *International Crop Science Congress* [online], http://www.cropscience.org.au/icsc2004/poster/1/3/2/852_fujiim.htm (2004).
39. Andersson, J. O. Lateral gene transfer in eukaryotes. *Cell. Mol. Life Sci.* **62**, 1182–97 (2005).
40. Batista, R., Saibo, N., Lourenc, T. & Oliveira, M. M. Microarray analyses reveal that plant mutagenesis may induce more transcriptomic changes than transgene insertion. *Proc. Natl Acad. Sci. USA* **105**, 3640–3645 (2008).
41. Tait, J. More Faust than Frankenstein: the European debate about the precautionary principle and risk regulation for genetically modified crops. *J. Risk Res.* **4**, 75–189 (2001).
42. Chataway, J., Tait, J. & Wield, D. The governance of agro- and pharmaceutical biotechnology innovation: public policy and industrial strategy. *Tech. Anal. Strat. Manag.* **18**, 69–185 (2006).
43. Bonny, S. Why are most Europeans opposed to GMOs? Factors explaining rejection in France and Europe. *Electron. J. Biotechnol.* **6**, [online], <http://www.ejbiotechnology.info/content/vol6/issue1/full/4/4.pdf> (2003).
44. Fukuda-Parr, S. (ed.) *The Gene Revolution: GM Crops and Unequal Development* (Earthscan, London, 2007).
45. Pinstrup-Anderson, P. & Schiøler, E. *Seeds of Contention: World Hunger and the Global Controversy over GM Crops* (Johns Hopkins Univ. Press, Baltimore, 2000).
46. Gaskell, G. *et al.* Europeans and Biotechnology in 2005: Patterns and Trends. A report to the European Commission's Directorate-General for Research. *EU Commission, Brussels* [online], <http://ec.europa.eu/research/press/2006/pdf/pr1906_eb_64_3_final_report-may2006_en.pdf> (2006).
47. Council for Biotechnology Information. Substantial Equivalence in Food Safety Assessment. *Council for Biotechnology Information* [online], <http://www.whybiotech.com/index.asp?id=1244> (2001).
48. Schurman, R. Fighting 'Frankenfoods': industry opportunity structures and the efficacy of the anti-biotech movement in western Europe. *Soc. Probl.* **51**, 243–268 (2004).
49. Schurman, R. & Munro, W. Ideas, thinkers and social networks: the process of grievance construction in the anti-genetic engineering movement. *Theory Soc.* **35**, 1–38 (2006).
50. Sato, K. *Meanings of Genetically Modified Food and Policy Change and Persistence: the Cases of France, Japan and the United States.* Princeton Univ. Princeton (2007).
51. Lezaun, J. Genetically Modified Foods and Consumer Mobilization in the UK. *Technikfolgenabschätzung: Theorie und Praxis* **3**, 49–56 (2004).
52. Madsen, S. T. The view from Vevey. *Econ. Polit. Wkly* **36**, 3733–3742 (2001).
53. Assayag, J. in *Globalizing India: Perspectives from Below* (eds Assayag, J. & Fuller, C. J.) 65–88 (Anthem Press, London, 2005).
54. Vinayak, R. A. & Bhaskar, G. (eds) *Rural Transformation in India: the Impact of Globalisation* (New Century Publications, New Delhi, 2005)
55. Shiva, V., Jafri, A. H., Emani, A. & Pande, M. *Seeds of Suicide: The Ecological and Human Costs of Globalization of Agriculture* (Research Foundation for Science, Technology and Ecology, Delhi, 2000).
56. Shiva, V. Resources, rights and regulatory reform. *Context* **3**, 85–91 (2006).
57. Shiva, V., The Pseudo-Science of Biotech Lobbyists. *Irish Seed Saver Association* [online], <http://www.irishseedsavers.ie/article.php?artid=123> (2006).
58. Shantharam, S. The Brouhaha about Bt-Cotton in India. *AgBioView* [online], < http://www.agbioworld.org/newsletter_wm/index.php?caseid=archive&newsid=2358> (2005).
59. Gopal, N., Qaim, M., Subramanian, A. & Zilberman, D. 2005. Bt cotton controversy. *Econ. Polit. Wkly* **40**, 1514–1517
60. Rao, C. K. Plant Biotechnology: Causes of Death of Cattle and Sheep in the Telegana Region of Andhra Pradesh in India. *Foundation for Biotechnology Awareness and Education* [online], <http://www.fbaeblog.org/2007/07/plant_biotechnology_causes_of.html> (2007).
61. Herring, R. J. Why did 'Operation Cremate Monsanto' fail? Science and class in India's great terminator technology hoax. *Crit. Asian Stud.* **38**, 467–493 (2006).
62. Herring R. J. Suicide Seeds? Biotechnology Meets the Developmental State. India in Transition. *Center for the Advanced Study of India, University of Pennsylvania* [online], http://casi.ssc.upenn.edu/india/iit_Herring.html (2007).
63. Weighardt, F. European GMO labeling thresholds impractical and unscientific. *Nature Biotechnol.* **24**, 23–25 (2006).
64. Barboza, D. Development of Biotech Crops is Booming in Asia. *The New York Times* [online], <http://query.nytimes.com/gst/fullpage.html?sec=health&res=9502E0DF123DF932A15751C0A9659C8B63> (2003).
65. Wright, Brian D and Pardey, Philip G. Changing intellectual property regimes: implications for developing country agriculture. *Int. J. Technol. Global.* **2**, 93–144 (2006).
66. Government of India Ministry of Science and Technology. Biotechnology: A Vision. *Department of Biotechnology, New Delhi* [online], <http://www.dbtindia.gov.in/publication/vision/visionshort.html> (2001).
67. Vandana, S. *Biopiracy: The Plunder of Nature and Knowledge* (South End, Boston, 1997).
68. Stone, G. D. Agricultural deskilling and the spread of genetically modified cotton. *Curr. Anthropol.* **48**, 67–103 (2007).
69. Herring, R. J. in *Social Movements in India: Poverty, Power, and Politics* (eds Ray, R. & Katzenstein M. F.) (Oxford Univ. Press, 2006).
70. Lybbert, T. J. Humanitarian use technology transfer: issues and approaches. *Int. J. Food, Agric. Environ.* **1**, 95–99 (2003).
71. J. I. Cohen, Poor nations turn to publicly developed GM crops. *Nature Biotechnol.* **23**, 27–33 (2005).
72. Gonsalves, C., Lee, D. R. & Gonsalves, D. The adoption of genetically modified papaya in Hawaii and its implications for developing countries. *J. Dev. Stud.* **43**, 177–191 (2007).
73. Davidson, S. N. Forbidden fruit: transgenic papaya in Thailand. *Plant Physiol.* **147**, 1–7 (2008).
74. Lipton, M. Plant breeding and poverty: can transgenic seeds replicate the 'green revolution' as a source of grains for the poor? *J. Dev. Stud.* **43**, 31–62 (2007).
75. Gold, A. G. Vanishing: seeds' cyclicality. *J Mater. Cult.* **8**, 255–272 (2003).
76. Ramanjaneyulu, G. V. & Ravindra, A. *Terminator Logic: Monsanto, Genetic Engineering and the Future of Agriculture* (Science for People/Research Foundation for Science, Technology and Ecology, New Delhi, I999).
77. ETC Group Communiqué #95. Terminator: The Sequel. *ETC Group* [online], <http://www.etcgroup.org/en/materials/publications.html?pub_id=635> (2007).
78. Jayaraman, K. S. Illegal Bt cotton in India haunts regulators. *Nature Biotechnol.* **19**, 1090 (2001).
79. Takeda, S. & Matsuoka, M. Genetic approaches to crop improvement: responding to environmental and population changes *Nature Rev. Genet.* **9**, 444–457 (2008).
80. Nuffield Council on Bioethics. Genetically Modified Crops: the Ethical and Social Issues. *Nuffield Council on Bioethics* [online], http://www.nuffieldbioethics.org/fileLibrary/pdf/gmcrop.pdf> (1999).
81. United Nations Development Programme. *Human Development Report, 2001: Human Development Report: Making Technologies Work for Human Development* (Oxford Univ. Press, New York, 2001). [online], <http://hdr.undp.org/en/media/completenew1.pdf> (2001).
82. James, C. *Global Status of Commercialized Biotech/GM Crops: 2007. ISAAA Brief No. 37.* (International Service for the Acquisition of Agri-Biotech Applications, Ithaca, New York, 2006).

Acknowledgements

I wish to acknowledge collegial advice from J. Thies, M. Zaitlin and E. Earle.

FURTHER INFORMATION

Ron Herring's homepage:
http://falcon.arts.cornell.edu/Govt/faculty/Herring.html
AGBIOS: http://www.agbios.com/main.php
Greenpeace International:
http://www.greenpeace.org/international
Pesticide Action Network International (PAN):
http://www.pan-international.org/panint/?q=en/node/33

ALL LINKS ARE ACTIVE IN THE ONLINE PDF