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Both Sides Now

Fallacies in the Genetic-Modification Wars, Implications for Developing Countries, and Anthropological Perspectives[1]

by Glenn Davis Stone[2]

It is rather remarkable that a process as esoteric as the genetic modification of crops would become the subject of a global war of rhetoric.[3] Yet for the past few years Western audiences have been bombarded with deceptive rhetoric, spin, and soundbite science portraying the wonders—or horrors—of the new technology. Books and full-page newspaper advertisements warn of a wrecked environment and food insecurity; children are brought to demonstrations dressed as monarch butterflies, swooning at the arrival of "GM (Genetically Modified) Corn Man." Meanwhile, organizations pour fortunes into television commercials and newspaper ads showing fields of healthy grain, smiling farmers, and poor children restored to health through genetically modified crops; the wonders of genetic modification are lauded in op-ed pages, brochures, and coloring books.

Since 1998, the most intense rhetorical battle lines of the genetic-modification wars have moved south to focus on food security in developing countries (Moffat 1999; Paarlberg 2000, 2001; Pinstrup-Andersen and Shiøler 2001). This emphasis is strategic for both sides as they seek issues that can be used to raise the stakes and images that can be readily manipulated. Nowhere is the war as hotly contested as in India. India offers gaunt children to support industry's claims of food shortages and impoverished smallholders to dramatize critics' warnings about endangering seed saving. It offers well-developed corporate and public biotechnology sectors and some of the world's most savvy green activists. It offers stories of cotton farmers committing suicide by the hundreds that both industry and its opponents claim to support their case (Stone 2002*a*).

Anthropologists should be gratified to see issues of farming, society, and technological change in developing countries thrust into the global gaze, but the move south has exacerbated an already polarized issue, ushering in a Golden Age of misinformation. Anthropology needs to follow this crucial debate and to contribute to it.[4] My focus here is on the core problem of the feeding of the growing populations in the developing world. This decomposes into two issues: the potential for biotechnology to reduce hunger by boosting food output and the need to take a discriminating view of genetically modified crops (e.g., distinguishing those from the corporate and those from the public sector) rather than treating genetic modification as a monolithic project. I examine the dominant industry and green positions on these two issues, using case material from India. The industry lobby plays the "Malthus card" by capitalizing on popular misconceptions about food supplies, and it intentionally obscures the differences between corporate and public crop biotechnology. The green lobby allows its political interpretation of hunger to blind it to the potential for some biotechnology to mitigate hunger, and—in an odd convergence of rhetorical strategies—it too obscures differences between corporate and public-sector offerings that are relevant to helping developing countries.

A proper examination of the competing discourses would recognize more variation within the sides of the debate than space allows, but on the two questions I am addressing the positions are salient enough to justify lumping the participants into pro- and anti-genetic-modification camps. The proponents are led by industry and organizations that it supports, such as the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) and various media sources appearing to represent concerned citizens ("Third Man" sources, in Ramp-

1. This paper draws on research in India supported by the Wenner–Gren Foundation for Anthropological Research and on training in biotechnology supported by the National Science Foundation. For comments and discussion I am grateful to W. Danforth, C. Fauquet, D. Ho, E. Jaworski, B. Lambrecht, R. Quatrano, A. Sudarshan Reddy, P. Richards, H. Shand, M. H. Suryanarayana, N. Taylor, G. Toenniessen, R. Tripp, J. Yadev, and R. Ziegenhorn, although none can be held responsible for opinions or errors. [Supplementary material appears in the electronic edition of this issue on the journal's web site (http://www.journals.uchicago.edu/CA/home.html).]
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3. "Genetic modification" refers to direct manipulation of an organism's DNA in the laboratory, characteristically by altering or inserting DNA sequences. Following common usage, "biotechnology" is used here synonymously with "genetic modification," although strictly speaking "biotechnology" also includes other technologies such as tissue-culture and genetic-marker-assisted breeding.

4. In contrast to the outpouring of advocacy literature, there has been little anthropological attention to the issue (see Marshall 2001; Bray 2001, 2002; and Tripp 2001*a*).

ton and Stauber's [2001] terminology).[5] Industry rhetoric on feeding developing countries is parroted by many academic biologists and public researchers.[6] Key sources of green rhetoric are Greenpeace, the Rural Advancement Foundation International (RAFI, now the ETC Group), the Turning Point Project (a coalition of Friends of the Earth, Sierra Club, and 20 other organizations), and foundations headed by Jeremy Rifkin and Vandana Shiva.

The European Debacle and the Move South

In the United States, penetration of genetically modified products encountered little resistance, attracting a low level of public interest that now seems remarkable (Bray 2002, Martineau 2001). The fate of the new technology was dramatically different in Europe. The first genetically modified product—clearly labeled and lower-priced tomato purée appearing in 1995—sold well. However, 1996 brought Monsanto's genetically modified soybeans, an unlabeled ingredient in countless processed foods that offered no clear benefit to the consumer, and opposition mushroomed until grocers began pulling genetically modified foods off their shelves in 1998. The reasons for the utter collapse of the European market for genetically modified products will occupy analysts for years to come (see accounts by Charles 2001 and Lambrecht 2001), but some pieces of the puzzle are clear. All agree that Monsanto mishandled the whole affair. Green organizations are more mainstream and distrust of government is higher in Europe, and for Britain the timing was exquisitely bad: the public had just learned in Spring 1996, after repeated assurances from government and the scientific establishment to the contrary, that bovine spongiform encephalopathy or mad cow disease caused the incurable variant Creutzfeldt-Jakob disease. The arrival of American genetically modified foods also coincided perfectly with the blossoming of the worldwide web (Lambrecht 2001), with its unprecedented opportunities for mobilizing grassroots resistance.

Monsanto mounted a media campaign in 1998 to win back support, and when this too failed it withdrew, regrouped, and made a major course change. By 2000 it and six other biotechnology firms had formed a public relations consortium called the Council for Biotechnology Information (CBI), with a reported war chest of $250 million (Lambrecht 2000, 2001:9) for TV and newspaper ads, web sites, and even coloring books. CBI advertising has from the outset concentrated on the need for genetically modified crops in developing countries. This was hardly an obvious strategy to adopt: over 99% of the acres in such crops were in the United States, Canada, and Argentina as of 1999. Yet this theme quickly came to dominate industry media. A recent visit to the CBI's web site found three major headlines, all concerning developing countries, and ten minor headlines, seven of which concerned those countries. Packets distributed by the CBI at the 2001 World Agricultural Forum contained 12 documents, 11 of which referred, in most cases in the first few sentences of the document, to improving food supplies for poor countries.[7]

The problem is that there was much more at stake in the South than sheer quantities of people and food. Genetically modified crops were recognized to be a key element in the potential industrial transformation of developing countries' agriculture. This is a deeply polarizing prospect, viewed by some as "depeasantization" or "penetration of capital" and a great threat (McMichael 2000, Araghi 2000) and by others as "modernization" and a great hope. It is a process already well advanced in industrialized countries, where, as Lewontin (2001) has put it, the farmer of a few decades ago

> saved seed from the previous year's crop to plant, the plow and tillage machinery was pulled by mules fed on forage grown on the farm, 40 percent of planted acreage was in feed crops, and livestock produced manure to go back on the fields. Now the seed is purchased from Pioneer Hi-bred, the mules from John Deere, the feed from Exxon, and the manure from Terra. . . . The consequence of the growing dominance of industrial capital in agriculture for the classical "family farm" has been the progressive conversion of the independent farmer into an industrial employee.

In industrialized countries, these are not the only inputs generated off-farm: with seeds and chemicals changing yearly, a substantial portion of the farmer's skill and knowledge has to come from seed vendors, extension agents, and web sites. Moreover, entire harvests are in-

5. I do not deal here with organizations opposing genetically modified crops on primarily environmental grounds, such as the Union for Concerned Scientists. Some would include the U.S. government agencies that regulate such crops—the Food and Drug Administration, the Environmental Protection Agency, and the U.S. Department of Agriculture—among the proponents. While a good case can be made for this, the involvement of government raises a set of issues that cannot be dealt with here, and therefore I avoid government media on the topic.

6. Although academic researchers need not generate profits, their reward structure nevertheless aligns them with industry rather than with efforts to benefit developing countries. Research competitiveness requires using the best available biotechnologies, most of which are in corporate hands—often after having been developed in academic biology departments and sold by university technology-transfer offices. Corporations typically allow free research use but assert intellectual property (IP) rights before crops can be distributed. As DeVries and Toenniessen (2001:73) point out, "The net result is that improved plant materials produced by academic scientist-inventors are highly IP-encumbered and commercially useful only to a big company having an IP portfolio large enough to cover most of the IP constraints. The international agricultural research system does not have such an IP portfolio and as a consequence the traditional flow of materials through the system is breaking down, particularly at the point where useful new technologies and improved plant materials flow from public sector researchers in developed countries to international centres and national crop improvement programmes in developing countries."

7. Industry interest in developing countries was not purely rhetorical. By the time the CBI began its campaign on feeding the world, genetically modified crops had a toehold in China, Mexico, and South Africa and test plots were in the ground in other countries such as India.

creasingly grown under contracts with food processors that render the farmer little more than a laborer. Much of the industrialized world's countryside may still appear bucolic, but many see its transformation as sinister (Magdoff, Foster, and Buttel 2000), indeed reminiscent of Blake's "dark Satanic mills" (Lewontin 2001).

In general, this is not true of the South. Developing countries' farming operations are highly varied, but the great majority are smallholdings that are seldom fully integrated into such industrial systems. Partial integration is certainly common, especially since the Green Revolution, but even those farmers who sell crops and buy inputs often strongly rely on local mobilization of inputs and consumption of produce (Netting 1993). Even where farmers are best-integrated into large-scale capital-intensive production, as in the Indian Punjab, the germplasm that is the backbone of agriculture remains a public good: the seeds are not patented, and farmers are free to save, replant, and sell. Not so with genetically modified crops and the intellectual property rights regimes that attend them, which represent "a convergence between high-tech methods of food production, a neoliberal development regime, and late-capitalist firms interested in profiting from the sale of intellectual property rights" (Gupta 1998:15). A remarkable number of Indian farmers, well before they had heard of genetic modification, were gravely concerned about the global movement toward privatization of seeds. Several hundred thousand farmers had rallied in Bangalore in 1992 and again in Delhi in 1993 to protest the General Agreement on Tariffs and Trade "Dunkel Draft," which mandated harmonized intellectual property controls in agriculture (Gupta 1998:291). The specter of the industralization of farming, privatization of germplasm, and eventual depeasantization in developing countries has proved a mighty stimulus to a range of green writers and activists. The global "antiglobalization" movement that can attract tens of thousands of ardent demonstrators to Seattle or Montreal is energized as much by genetic modification as by any other single issue.

In India, the test plots of genetically modified cotton became a lightning rod for these concerns and were uprooted by protesters. The same concerns have helped make an international star of Vandana Shiva, whose voluminous writings depict genetic modification as threatening an idyllic traditional agrarian culture that is ecologically stable, seed-saving, biodiverse, noncommercial, and female-oriented (Shiva 1993, 1997, 2000*a*). It is a vision of society just as spiritual as Blake's vision of England, even if it cites the Upanishads rather than the Bible.

If these are the larger issues behind the clash, the war of words has been given specific shape by two technological developments that, although still years from actual use, have come to dominate the genetic-modification media: "Terminator" and Golden Rice.

In 1998 the USDA took out a joint patent with the cotton seed company Delta Pine & Land for an inducible genetic mechanism for producing plants with sterile seeds (Feder 1999). This would oblige farmers to buy new seed each year rather than replanting. The patent was a public relations windfall for genetic-modification opponents; it was dubbed "Terminator" by RAFI and used to direct international attention to the way in which genetically modified crops threatened developing countries' farmers (Steinbrecher and Mooney 1998). Industry (and the USDA) avowed that the technology would actually benefit those farmers by attracting investment in crop development, but the issue was enough of a public relations problem that Monsanto promised not to use the technology and never did acquire Delta. The fact that not a single "Terminator" seed has been marketed to date has not slowed the rampant spread of misinformation about "Terminator" seeds. I have found that many farmers in rural India are convinced that all genetically modified seeds are "Terminator" seeds, as are many people in the West.[8]

Golden Rice has played a parallel role in pro-genetic-modification campaigns. In this rice, the addition of three exotic genes leads to the production of beta carotene in rice endosperm. It is hoped that it will mitigate the problem of Vitamin-A-deficiency blindness in poor children on rice-based diets. Golden Rice, with its lead developer, Ingo Potrykus, appeared on the cover of *Time* in July 2000, billed as a plant that "could save a million kids a year." It instantly became what many have called the "poster child for biotechnology." Some media uses of this technology have been as shameless as any uses made of "Terminator," with figures on the prevalence of Vitamin-A-deficiency blindness inflated and the rice's limitations glossed over.

Since the emergence of "Terminator" and Golden Rice, further developments have encouraged developing-countries-based campaigning by both sides. The industry continues to be embarrassed by cases of contamination, including canola contamination in the U.K., the StarLink taco contamination, and repeated contaminations of organic farms. Such headlines are less likely in developing countries, where few genetically modified crops are actually being planted and monitoring of farms and food is less rigorous. These themes remain popular with critics as well, as consumers continue to eat genetically modified foods without incident and as scientific concern over some environmental dangers (such as butterfly-killing genetically modified pollen) dwindles.

The level of rhetoric on genetically modified crops in developing countries remains very high, exerting a strong polarizing effect on the public and the scholarly/scientific community as well. While the following analysis was not necessarily conceived as an attempt to forge a middle ground, it does arrive at a ground quite apart from the orthodox industry and green positions.

8. Delta's "Terminator" is only one of 14 "genetic use restriction technologies" patented to date (RAFI 2001).

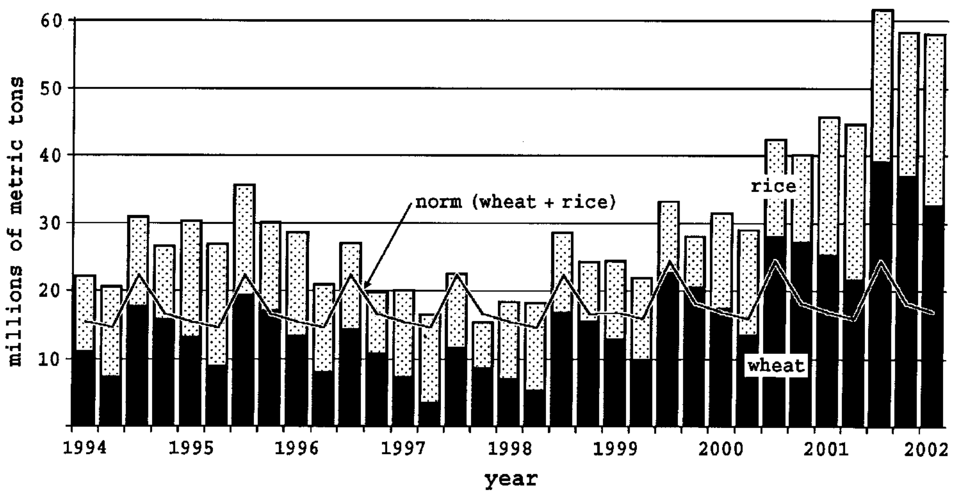

FIG. 1. *Growth of India's buffer stocks of wheat and rice, with seasonally adjusted norms for combined wheat and rice. Bars indicate stocks on the first days of January, April, July, and October. Data from Indian Ministry of Finance Economic Surveys 2000–2001 and 2001–2002 with update from* Business Line.

The Industry Lobby

PLAYING THE MALTHUS CARD

The core element in pro-genetic-modification discourse is the warning about current and future food shortages and the need for crop genetic modification to avert famine: "Agri-biotechnology offers promising means to a more sustainable agriculture. . . . This is a critical need in developing countries, where over 90% of the world's 11 billion people will be living in 2050" (ISAAA 2001). According to the CBI web site (November 6, 2001), "Over the past 40 years, the world's population has doubled to 6 billion, and according to United Nations projections, it could climb as high as 10.7 billion in 2050 with most of the growth occurring in the poorest and least developed regions of the world. . . . Already, UN statistics show that 800 million people are chronically malnourished. . . . Biotechnology could increase crop production in the developing world by 25 percent." Undergirding this theme is the Malthusianism that is so deeply ingrained in the Western (particularly American) worldview that the public generally assumes overcrowding when there is hunger and hunger where there is crowding (Stone 2002*b*).

This dogma has always been more consistent with the political interests of corporations than with empirical reality (Ross 1998). These scenarios incorporate an odd reversion to Malthus's late-18th-century belief in the inelasticity of agriculture, as exemplified in Martina McGloughlin's widely repeated claim that "unless we will accept starvation or placing parks and the Amazon Basin under the plow, there really is no alternative to applying biotechnology to agriculture" (UC Davis 1999). It is unclear whether this position results from genuine ignorance of the voluminous literature on intensification (for recent overviews, see Stone 2001*a*, *b*), but it is not as forgivable today as it was in Malthus's day, especially coming from advocates who claim the authority of "science."

More problematic still is the repeated attribution of hunger to overall food shortages. While some genetic modifications of crops probably can mitigate hunger, it has been repeatedly shown that overall food shortages have had little to do with famine throughout history (e.g., Sen 1981). When we look at India we find something even more perverse. Farm overproduction is a recognized problem in developed countries, but it is not expected in India, where a quarter billion people are believed to be malnourished and more than 1.5 million children die each year from diseases linked to malnutrition (Sharma 1999). It is hard to imagine a scenario more damning to the Malthusian dogma than the current situation: in recent years, with Malthusian justifications coming at an unprecedented rate from the pro-genetic-modification camp, India has faced a deepening crisis of overproduction.

Through the Food Corporation of India (FCI), the state buys wheat and rice (and small amounts of other crops) at guaranteed "minimum support prices," storing the food as buffer stocks in large granary facilities. These stocks are used to ensure food security, to moderate market-price fluctuations, and to provide low-cost food to the poor. The government establishes desired levels (norms) for stocks; these norms fluctuate seasonally according to dry- and wet-season harvests. However, it continues buying at its support prices even when stocks exceed norms, and the procurement of wheat and rice has for years greatly exceeded norms (fig. 1), reaching levels far beyond what the FCI wants or can handle (Parsai 2000). By 2001, with combined wheat and rice stocks

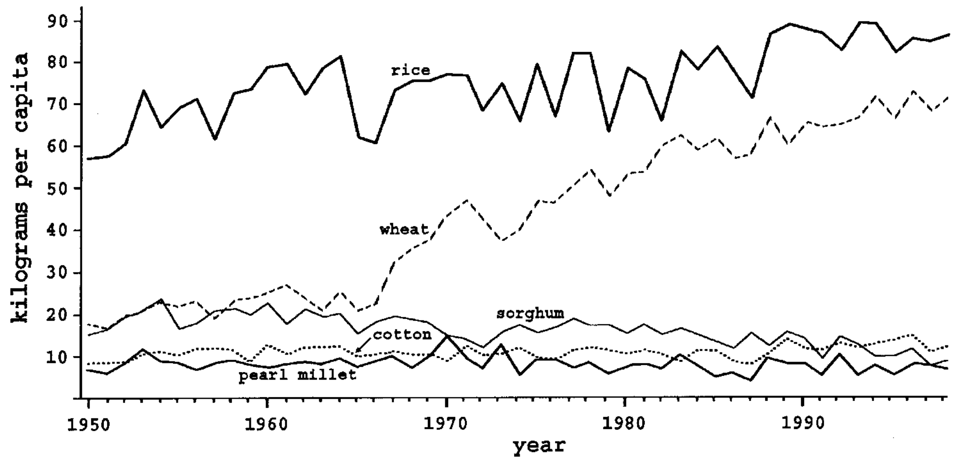

FIG. 2. *Per capita crop production in India, 1950–99. Data from Indian Ministry of Agriculture (http://www.agricoop.nic.in).*

approaching 30 million (metric) tons above the norm, it was reported that hundreds of thousands and perhaps millions of tons were rotting in the granaries (*The Hindu*, December 20, 2000; Press Trust of India 2001). By January 2002, combined stocks had reached 58 million tons—41.2 million tons above the norm (*Business Line*, January 18, 2002).

This regime of overproduction is based on the famous Green Revolution crops that are credited with averting widespread famine in the 1960s. India's need for foreign grain at the time was quite real, even if its causes were hardly Malthusian (Perkins 1997). In fact, the Indian grain hunger that had spurred the development of Green Revolution crops was itself a result, in part, of U.S. overproduction. U.S. grain overproduction, especially of maize, surged after World War II in part because of fertilizer-intensive varieties developed to absorb nitrogen from the wartime industry (Kloppenburg 1988). Through programs such as PL-480 (The Agricultural Trade Dvelopment and Assistance Act of 1954), foreign food aid was intended both to absorb the overflow and to check the spread of communism in food-deficit areas such as India. India in the 1950s needed to make up for the loss of most of its Punjab breadbasket to Pakistan without diverting investment away from industrialization. Its willingness to absorb substantial amounts of the cheap U.S. grains had serious long-term consequences (Perkins 1997:157):

> The huge supplies of American grain that flowed into India during the 1950s and early 1960s accomplished the function intended by Nehru's government, to keep Indian grain prices down. In fact, prices were so low that Indian domestic production stagnated. Indian farmers simply could not compete against grain sold at a loss by the American government, so they stopped trying and Indian production failed to rise fast enough to meet increasing domestic demand.

Then in 1965–67 a severe drought forced even greater food imports and precipitated a national sense of urgency. By 1968 Green Revolution wheats had arrived and the FCI had begun subsidizing production of irrigated wheat and rice. A pattern had been established that continues today.

The costs of India's overproduction are varied and exorbitant. Many large farmers are paid inflated rates for grains, and surpluses after the offtake for the poor must be liquidated at a substantial loss. India has tried to barter surpluses with little success and now is increasingly releasing grain to private traders at below its acquisition cost (*Economic Times*, June 11, 2000; *Business Line*, March 29, 2001). There are crippling costs for maintaining the stocks in granaries: the one-year cost for the 41.2-million-ton overstock would be over $2.1 billion (*Business Line*, January 18, 2002). There are also troubling long-term costs to sustainability. The grain in the overflowing granaries is from Green Revolution plants highly dependent on irrigation; since 1950 the percentage of the wheat crop under irrigation has risen from 34% to 86% and that of the rice crop from 32% to 51%. This trend comes at the expense of most sustainable crops. Figure 2 compares long-term patterns in production of the more heavily irrigated crops (rice and wheat) with those in the production of the drought-tolerant crops of pearl millet and sorghum, which had for millennia played a major role in Indian subsistence.

The fact that so many go hungry while the granaries are bursting is widely recognized in India; it provokes outrage on editorial pages almost daily (e.g., Venkatesan 2001; *The Hindu*, December 20, 2000; Swaminathan 2001; Drèze 2001; Bakshi 2001; Reddy 2001). That this stark refutation of the Malthusian dogma would be foisted on a gullible public reflects a cynical ruthlessness.

I am not suggesting that India or any other developing country stop the ongoing process of crop improvement. The issue is the Malthusian justifications that permeate the debate on genetically modified crops for countries such as India. While ostensibly attacking opponents for neglecting the big picture—the need to produce more food for developing countries—advocates actually obscure the real picture, in which the world's hungriest country is already paying a high price for overproduction. Rather than forgoing critical analysis of genetically modified crops on the pretext of a food emergency, we need a *more* discriminating analysis of the effects of specific plant transformations on the feeding of the poor. The head of an industry-backed foundation recently lashed out at critics, saying that "to turn a blind eye to 40,000 people starving to death every day is a moral outrage. . . . We have an ethical commitment not to lose time in implementing transgenic technology" (Macilwain 1999). I suggest that the moral outrage is the use of the hungry to justify genetically modified products without explaining how these products will mitigate hunger; as the case of India shows, simply raising food output may be the last thing that is needed. Malthusian biotechnologists need to explain why crop genetic modification will feed hungry Indians when 41.2 million tons of excess grain will not.

BLURRING THE BOUNDARIES

U.S. audiences have been inundated in recent years by corporate promotions of Golden Rice. Repeatedly the promotions remind us that this boon is possible only through genetic modification and that industry "technologies are being donated to the poor." Monsanto in particular has sought and won plaudits for its role. In response to its press releases, headlines and editorials appeared nationwide in 2000 announcing that "Monsanto Offers Free Licenses to Make Golden Rice" and "Monsanto's Methods—Golden Rice Could Be a Life-Saver." In fact Monsanto made only a very minor contribution to the development of Golden Rice, which emerged not from the corporate sector (Nestlé refused to fund Potrykus) but from the public sector, principally the Rockefeller Foundation. Its only role was the loan of the CaMV 35S viral promoter on which it holds a patent, which will likely be replaced before anyone eats a grain of Golden Rice.[9]

The distinction between the corporate and public sectors of biotechnology is insufficiently appreciated by many observers. This is not an accident: the sectoral boundaries are blurred, and the corporate sector has taken a strategic interest in this blurring.[10] Still, there remains a fundamental difference between entities aimed at improving human welfare and those with a fiduciary responsibility to shareholders, and this difference is key to a discussion of genetically modified crops for developing countries. There is increasing recognition of "multiple publics" (Sagar, Daemmrich, and Ashiya 2000), but too little attention has been paid to "multiple biotechnologies." While the world of biotechnology can obviously be parsed much more intricately, this divide is crucial with respect to benefiting developing countries.

Industry's promotional use of Golden Rice is intended to obscure differences between the sectors of biotechnology as much as it is to draw attention to this one invention, reinforcing a monolithic and positive image of genetically modified crops. A more discriminating perspective would conclude not that genetic modification per se is beneficial to developing countries but that corporate and public modes of research tend to yield different kinds of products with different proprietary arrangements. *This* is what needs to be examined but is being obscured by the industry use of such "humanitarian" crops.

The Green Lobby

DENYING THE POTENTIAL

Critics of genetic modification stress that hunger in developing countries results from poverty rather than food shortage (e.g., Lappé, Collins, and Rosset 1998, Rosset 1999); this is demonstrably true, and the Indian case goes even farther in showing the deleterious effects of overproduction. Yet it does not follow that crop genetic modification has nothing valuable to offer to developing countries. The characteristic green position is that genetic modification will exacerbate the poverty behind hunger.[11] For India, this perspective is argued most strongly by Vandana Shiva, who warns that genetically modified crops will only hamper developing countries' food security by discouraging the cultivation of subsistence crops and disrupting the "free exchange of seed" (2000*a*:8). Therefore, engineering viral resistance in crops is seen as little more than a blunder that would create new viruses (Rifkin 1998:85), while Golden Rice is attacked as a "hoax" (Shiva 2000*b*) and a "Trojan Horse" (RAFI 2000) that will facilitate the penetration of cor-

9. A "promoter" is a DNA sequence located close to a gene on the chromosome and responsible for determining when and under what conditions the gene functions. For an explanation of how such naturally occurring genetic elements are patentable, see Stone (2002*b*).

10. The "public" terminology is misleading. Most of the humanitarian research is conducted in private foundations funded by other private foundations; meanwhile, a truly "public" agency like the USDA follows a research agenda slanted toward corporate priorities.

11. Perhaps the closest the green literature comes to recognizing the potential benefits of genetic modification to developing countries is Altieri and Rosset's (1999) statement: "Although there may be some useful applications of biotechnology (i.e. the breeding of drought resistant varieties or crops resistant to weed competition), because these desirable traits are polygenic and difficult to engineer, these innovations will take at least 10 years to be ready for field use."

porate technology while contributing nothing to nutrition because of its low beta-carotene level. I would suggest that industry's cynical use of Golden Rice does not keep it from holding some promise for developing countries, especially since the carotene level can probably be raised. The more important point is that the debate on the value of genetically modified crops to developing countries must not hinge only on this one overhyped technology. A wide variety of public research projects better illustrate the potential of crop genetic modification (Conway and Toenniessen 1999). In India, the sorghum and pearl millet that are discouraged by Indian agricultural policy are undergoing improvement through genetic modification by public researchers at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT); genetic modification of the pigeonpea also appears highly promising (Sharma and Ortiz 2000). But perhaps the most interesting example of promising crop genetic modification for developing countries is cassava.

Although not currently a major Indian cultivar, cassava (*Manihot esculenta*) is a crucial subsistence crop worldwide, ranked third (behind rice and maize) as a source of dietary calories in the tropics. It has special value in developing countries' farming because it does well on poor soils and with low rainfall and because as a perennial it can be harvested as required. Its wide harvesting window allows it to act as a famine reserve and is invaluable in managing labor schedules (Stone, Netting, and Stone 1990). It is also a potential cash crop for farmers, supplying growing demands in starch markets. However, cassava production has severe constraints, including rapid postharvest deterioration of the roots and serious deficiencies in protein and vitamins. Propagation via stem cuttings results in accumulation of pests and diseases in the planting material. African cassava crops have been devastated by mealybug and mosaic virus in recent years and are continuously threatened by bacterial blight disease (Thro et al. 1999:146). Attempts to remedy these problems through breeding have been frustrated by the plant's shy and asynchronous flowering, which hinders the crossing of elite parents, by wide segregation of desired characteristics upon outcrossing, and by strong inbreeding depression, which prevents backcrossing to parental material. Cassava breeding programs are bulky and lengthy, calling for screening of tens of thousands of seedlings and often requiring up to ten years for an improved variety to reach the farmer. These factors result in a growing deficiency in cassava farming as new diseases appear, old diseases and pests spread, and crop improvement programs face obstacles that rice, wheat, and maize breeding have never faced. Cassava yields are roughly one-eighth of what is possible under field trial conditions, a larger gap than for any other major subsistence crop (Toro and Atlee 1980:13; Taylor et al. 1999) and one which illustrates this crop's enormous unrealized potential.

Genetic modification of cassava by public research shows promise for addressing many of these problems. The Centro Internacional de Agricultura Tropical (CIAT) is currently creating a map of the cassava genome that will help breeders introduce genes for insect and disease resistance and generating the genomic tools that will lead to identification and isolation of the genes responsible for specific traits within the crop. The International Laboratory for Tropical Agricultural Biology (ILTAB)[12] has succeeded in genetically modifying cassava to produce plants with elevated resistance to cassava mosaic disease (Taylor et al. 1999, Taylor and Fauquet 1997). These plants can be field tested in Africa once appropriate biosafety regulations are in place. Other ILTAB research is focused on mitigating cassava's postharvest deterioration and raising its protein content.

Given the earlier discussion of the Indian food glut, it is important to clarify why genetically modified cassava should contribute to the nourishment of developing countries' populations. Cassava is a subsistence crop of the poor and one that produces well below its potential. Because of obstacles to improvement through conventional means, its productivity has risen only a fraction of that achieved for rice, wheat, and maize. Yet it can be a cash crop, too, and its marketability would be greatly enhanced by reduced postharvest deterioration. This flexibility of combined use-value and exchange-value is invaluable to smallholder economic sustainability (Stone 2001*a*). Cassava is a vegetatively propagated crop and thus likely to remain beyond the proprietary control of agricultural capital; it is virtually impossible to wrest control of the plant's reproduction from the farmer. Finally, in contrast to modern varieties that offer higher yields only by absorbing higher levels of water and fertilizer (the hallmark of Green Revolution wheats), cassava's ability to thrive with low fertility and moisture will not be compromised by the modifications being envisioned.

There are other highly promising crop modifications under way, including work on apomixis. Apomixis is a form of asexual reproduction or natural cloning that occurs in some wild plants. It could lock the benefits of heterosis into a replantable pure line, potentially allowing producers to maintain an apomictic seed variety indefinitely. Genetic modification is greatly expediting this research, notably on maize, pearl millet, and rice. Where greens have taken a position on apomixis it has been simply to denounce it—portraying it as a means for seed companies to reduce production costs (de la Perriere and Seuret 2000:34–35). However, the vital question of who will benefit from apomixis is not at all settled (Bicknell and Bicknell 1999, Bellagio Apomixis Declaration 1998). It is a technology that could *increase* the farmer's control over crop reproduction (in counterpoint to "Terminator" technology). Apomixis, in which government, corporate, and public laboratories are all involved, underscores the need for increased scrutiny of the different offerings of corporate and public research. Yet throughout the anti-genetic-modification literature, from Greenpeace to Jeremy Rifkin to Vandana Shiva to the Natural

12. Part of the Donald Danforth Plant Science Center, St. Louis, Mo., ILTAB provides training to scientists from developing countries and conducts research on tropical crops and crop diseases.

Law Party, there is an eerie silence about the accomplishments and potential of public research.

BLURRING THE BOUNDARIES

The studious avoidance of public genetic-modification research results from the position that crop genetic modification should be judged and rejected as a whole rather than analyzed as the varied enterprise that it is. The green media show a remarkable convergence with the corporate media in calling for a verdict on the monolithic entity of genetic modification. Dismissing public research allows bold condemnations of all crop genetic modification, as in the Turning Point Project's "Biotechnology = Hunger" advertisement. Just as industry urges that crop genetic modification in general be supported because the public sector is working on Golden Rice, greens urge that crop genetic modification in general be condemned because the corporate sector is working on "Terminator."

Complicating the issue are the rapidly evolving links between corporate and public genetic modification. For instance, rights to Golden Rice for industrialized countries have wound up in the hands of the AstraZeneca (now Syngenta) Corporation in exchange for its assistance with patent arrangements. The scientists working on the rice believed that there were dozens of patent obstacles to be overcome before the technology could ever be used (Kryder, Kowalski, and Krattinger 2000). Arguing that there were actually no more than 11 patent constraints for developing countries, RAFI complained that the developers had "surrendered a decade of public funding to the commercial and PR interests of the biotech industry" (RAFI 2000; see Potrykus 2000). Whether or not the corporate partnership was avoidable, the fact remains that Golden Rice will be freely available to the poor. At the same time, several developing-country-oriented genetically modified plants from the public sector, such as virus-resistant rice and sweet potatoes, are being blocked by corporate patent constraints. It should be clear that, while there are deep linkages between the corporate and the public sector, there are also essential differences.

The greens' scorn for public research appears to some to reveal a lack of genuine concern for the welfare of developing-country populations (Nash 2001), but it more likely results from a perceived need to engage the struggle on a large scale with strong financing and a wide following. Large, ardent followings of check-mailing opponents of genetic modification are better mobilized by bold black-and-white slogans than by critical evaluations of the potential effects of different genetically modified products. Mass marketing has led to a shameless "dumbing down" of the issues. Greenpeace, with a global presence and around 4 million paying supporters (Purdue 2000:73), offers one of the boldest condemnations of genetic modification; it is no accident that right next to the "No Genetic Modification" banner on its web page is the "click here to join" button.

However, the greens' demonization of genetically modified crops has effects that are contradictory to their values. Promoting blanket disapproval of such crops helps drive public-sector genetic modification into the arms of industry. Genetic modification is expensive, and most public projects are in a constant struggle for funding. Industry provides some funds and access to genetic materials; greens provide no funding and obstruct philanthropic investment (ABC News Online 2001). Green activists may claim to have developing countries' interests at heart, but many public researchers have devoted their careers to improving nutrition for the poor, often spurning better-paid positions in industry. Many actually share greens' disapproval of increasing corporate control over developing countries' food production, but they can hardly be blamed for disdaining activists who demonize public research along with corporate projects. They may fairly ask green critics why they do not approve of ongoing research such as cassava modification that is explicitly tailored to improving food security for the poor.

Anthropological Perspectives

As both product development and rhetoric have turned to developing countries, the genetic-modification issue has taken on some urgency for anthropology. Anthropologists and allied researchers have long devoted detailed attention to the agricultural systems that are being caricatured by both sides, and anthropological input is needed now.

Anthropology is the primary discipline studying cultural issues in developing countries, and even anthropologists who work on no issues connected to genetic modification are likely to take a position on the merits of genetically modified crops for those countries. The polarized and often manipulative positions should be given critical scrutiny. I have argued that the situation is more complex than either the industry or the green position allows for: The world is not in dire need of higher production, and even in some developing countries high costs are being paid by overproduction. Rather than needing to be less discriminating about methods of boosting production, as the Malthusian claims suggest, we need to be more discriminating. However, green intransigence notwithstanding, genetic modification does have the potential to help solve pressing problems in crop improvement and, moreover, to help fill human stomachs rather than government granaries.

Anthropology can also help increase the empirical veracity of the global debate. A prime example concerns seed saving. In theory, crop biotechnology operates as a mechanism of capitalist penetration through appropriation of the farmer's control over seed (Kloppenburg 1988), and green activists have depicted Indian farming systems as running entirely on saved seed and reciprocal exchanges (e.g., Shiva 2000*a*:8). The reality is not so tidy. The ability to save seed is undoubtedly important, but seed *sale* is a crucial strategy for many smallholders, and, furthermore, many farmers choose to buy seed even when they could save it (Tripp 2001*b*, Tripp and Pal

2001). As such aspects of indigenous agricultural systems are featured in global debates, anthropological field research takes on new importance.

Anthropology can also help raise the level of global debate through research and writing on synthetic issues that are overlooked in media wars. Three such topics are the following:

The *social life of genetically modified seeds*. Virtually all parties agree that genetically modified crops require regulation, but there is already rapid spread of unregulated plants in developing countries. In India, genetically modified cotton was being grown illegally on an extensive scale well before its approval in March 2002 (*Times of India*, October 19, 2001; Jayaraman 2001). It is not known to what extent genetically modified tomato and other seeds are brought into Mexico by returning agricultural labor migrants, but there is little doubt that it is happening. How these seeds move through social channels, crosscutting national-level regulation, is a problem in need of study.

Biotechnology and farmer deskilling. Anthropologists have stressed the vital role of skill in sustainable smallholder agricultural production (Netting 1993, Richards 1989) and the importance of social channels for moving the information needed for "skilling" (Richards 1997). American agricultural history shows how closely agribiotechnology can be linked to farmer deskilling (Fitzgerald 1990); research is needed on how agricultural biotechnologies may already have caused deskilling and how information flow may be further impeded with genetically modified seeds (Stone 2002*a*).

Control of the research agenda. I have stressed the need to discriminate among potential effects of different crop modifications and institutional arrangements on farmers. There is a world of difference between the proprietary herbicide-tolerant cotton and publicly available virus-resistant cassava: one is a nonreplantable cash crop engineered to accommodate other industrial inputs, the other a vegetatively reproducing subsistence crop with a major vulnerability remedied. In industry, crop transformations are pursued on the basis of profit potential, but priorities in public research are less clear and more negotiable. With increasing corporate backing for public biotechnology research (e.g., within the Consultative Group on International Agricultural Research [CGIAR] system [Pinstrup-Anderson and Cohen 2000]), research agendas are in the balance. On what information will priorities in plant transformations be based? Crops function as construction materials, animal fodder, status symbols, ritual items, boundary markers, statements of ethnic identity. Their characteristics are closely tied not only to the characteristics of other crop plants (Stone, Netting, and Stone 1990) but to migration, witchcraft, and gender (Stone 1997, Stone and Netting 1995). Anthropology's synthetic perspective on crops is much needed.

Crop genetic modification is an issue of profound importance, with far-reaching implications for the environment, the planet's food supply, the integrity of farms, and the ownership of nature. Developments in recent years have left the agrarian societies of developing countries at the center of a global dispute that is serving those societies very poorly. Anthropology has an opportunity and a duty to bring its knowledge base and research abilities to bear on this problem.

Comments

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Are all anthropologists as surprised as Stone to find genetic modification of crops the subject of "a global war of rhetoric"? I thought that they were aware that technical choices are simultaneously political choices, not always convergent with the fuller aspirations of a free, democratic society. Anthropologists have in fact criticized technologies pursued without concern for the environment or social displacement, noting that as long as researchers attempt to maintain political "neutrality" their research will always serve those who are in a position to dictate the research agenda. Many of the "neutral" agricultural scientists who promoted the Green Revolution had profound social and political effects on Third World agriculture, yet they disclaim responsibility for anything but the purely technical aspects of their work.

Jennings (1988) argues that

> perhaps the most significant consequence of the rise and spread of international agricultural research . . . is with respect to the production of knowledge, not plants. The dramatic transformation that occurred in Mexican agriculture following the establishment of CIMMYT [the International Maize and Wheat Improvement Center] moved well beyond farmers' fields to include public institutions. The Rockefeller Foundation's success in patterning the agricultural colleges, research stations, and national bureaucracies according to a U.S. model signaled the gradual demise of struggles regarding the distribution of land, water, and capital.

He shows that the Foundation ignored the views of the geographer Carl Sauer, who, while agreeing that productivity was part of the problem, directed attention to the social factors he believed to account for poverty and wrote that "a good aggressive bunch of American agronomists and plant breeders could ruin native resources for good and all by pushing their American commercial stocks. . . . And Mexican agriculture cannot be pointed toward standardization on a few commercial types without upsetting native economy and culture hopelessly" (quoted in Wright 1984:137).

International agricultural development has been dominated by technical questions, ignoring more fundamental social and economic ones and neglecting traditional farmers' knowledge and perspectives from the social sciences. The result has been the imposition of inadequate development models of which biotechnology is the latest variant. This is especially dangerous when one considers that biological research in agriculture is no longer in the public domain but under the direction of corporations that influence its direction in unprecedented ways.

Developments in biotechnology reflect a decision-making process in which commercial interests override societal and environmental concerns. Biotechnology has been imposed in the United States without farmers' or public participation, and the same strategy is being pursued in developing countries. If social issues had not animated the "green" responses that Stone considers deceptive and dubious, key points about the environmental and social impacts of genetically modified crops would have been ignored or suppressed by the $250 million Council for Biotechnology Information.

Biotechnology proponents argue that expansion of transgenic crops to the Third World is essential to feed the poor, reduce environmental degradation, and promote sustainable agriculture. These promises do not match reality, and anthropologists have a responsibility to expose them. Hunger is linked to poverty, lack of access to land, and maldistribution of food, and by deepening inequality biotechnology is bound to exacerbate it (Lappé, Collins, and Rosset 1998). People exhibit Vitamin A deficiency not because rice contains too little Vitamin A but because their diet has been virtually reduced to rice. Golden Rice must be seen as a one-dimensional attempt to solve a problem created by the Green Revolution—diminished crop and dietary diversity—and as unlikely to make any lasting contribution to well-being (Altieri 2000*b*).

Biotechnology is protected by patents and intellectual property rights and thus threatens the millennia-old tradition of farmers' saving and exchanging seeds. The new seeds are also more expensive and ill-suited to marginal environments. Large investments through public–private partnerships are unlikely to help developing countries acquire the scientific and institutional capacity to shape biotechnology to the needs of small farmers. Corporate intellectual property rights are a major barrier, as government research institutes will have to negotiate license agreements with various companies before an improved variety can be released (Krimsky and Wrubel 1996).

The ecological effects of genetically engineered crops are not limited to pest resistance and the creation of new weeds or virus strains, a key issue in centers of origin (Rissler and Mellon 1996). Transgenic crops can produce environmental toxins that move through the food chain and may also end up in the soil and water, affecting invertebrates and ecological processes such as biological control and nutrient cycling. Moreover, the large-scale landscape homogenization with transgenic crops will exacerbate the ecological vulnerability already associated with monoculture agriculture (Altieri 2000*b*).

There is widespread consensus that yields have not increased with transgenic crops; rather, soybean yields tend to be lower, cotton yields are unchanged, and maize yields are higher only under high pest pressure. No biotechnological breakthrough to boost yields of resource-poor farmers is on the horizon (Altieri 2001*a*). Savings in insecticide use are insignificant when compared with the savings derived from integrated pest-management strategies. Bt crops are justified only when borers reach outbreak proportions; in most years farmers can reduce pests with rotations or strip-cropping (Altieri 2000*a*).

There are proven agroecological alternatives to biotechnology that are cheap, accessible, risk-averting, productive in marginal environments, environment- and health-enhancing, and culturally and socially acceptable. A recent analysis of 208 agroecologically based initiatives documents increases in food production over some 29 million hectares, benefiting nearly 9 million households. The promotion of sustainable agricultural practices has led to 50–100% increases in per-hectare food production (about 1.71 tonnes per year per household) in rain-fed areas, affecting some 3.58 million hectares cultivated by about 4.42 million farmers (Pretty and Hine 2000). Such yield enhancements are a real breakthrough in food security (Uphoff and Altieri 1999). New approaches and technologies have the potential to raise cereal yields 50–200%, increase stability of production through diversification and soil/water management, improve diets and income, and contribute to national food security and export (Uphoff 2002). Major changes in policies, institutions, and research and development are required to ensure that agroecological alternatives are adopted, made equitably and broadly accessible, and multiplied (Pretty 1995).

Indigenous and peasant movements throughout the Third World have repeatedly rejected corporate-controlled biotechnology. Are anthropologists prepared to abandon their neutrality and support developing-country farmers in developing their vision of agriculture? Are they ready to challenge corporate control over the food system? Are they willing to encourage partnerships between governments, international public organizations, NGOs, local universities, and farmer organizations to assist and empower poor farmers to achieve food security, increased incomes, and natural resource conservation?

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Stone has written a brilliant article debunking the extreme and at times irrational posturing of multinational corporations and greens in the great genetic-modification debate. His analysis of industry's shift from "Terminator" to the benevolence of Golden Rice is perceptive and in my belief correct. While the positioning and repositioning of the multinationals can be ascribed to the exigencies of market penetration and profit, it is not clear what drives the greens in this debate. Their high-decibel critique of genetic-modification technologies, which at times descends to the level of sheer distortion of facts, has had considerable impact in Europe and other developed countries. The influence of a stance also depends upon receptivity of the citizens. After all, what has Europe lost in terms of quality of life by rejecting genetically modified foods? It may be that while other innovations—refrigerators, cars, computers, cell phones—are perceived as "essential," genetically modified food is not seen from a similar perspective. The situation, both economic and political, is far more complicated in the developing countries. Population is increasing, pressure on natural resources such as water (both quality and quantity) and soil health is mounting, and modern industry, with its emphasis on efficiency and automation, can absorb only a small fraction of the numbers of employable young people. Around 70 percent of the population in India still lives off the land in rural communities. Any new technologies that have implications for higher productivity and sustainability should be of great interest to developing countries.

Agriculture is facing many serious challenges in India. The overproduction of wheat and rice (overproduction here is also related to lack of purchasing power among the poor) that Stone has pointed out is due to the following factors:

1. Wheat and rice are mostly grown under irrigation with copious fertilizer input, and the government of India is providing huge financial subsidies for fertilizer and electricity to sustain the cultivation of these two crops.

2. Agencies of the government procure these two cereals at a minimum support price, assuring farming communities of monetary returns.

3. Because wheat and rice are self-pollinated crops, farmers' expenditure on seed is minimal.

4. The best breeding programmes of the CGIAR system's institutes (CIMMYT for wheat, IRRI for rice) are for these two crops, and so are the best national efforts in breeding. These endeavours ensure yield stability and, therefore, reasonable returns.

Compared with that of wheat and rice, production of leguminous grain crops such as chickpea, pigeonpea, mung, and oilseed crops (mustard, groundnut, safflower [mostly grown in the dryland areas of west and central India]) is stagnating. In 1998–99 India imported U.S. $1,694 million in edible oils. Most dryland crops are suffering from biotic stresses, and genetic engineering technologies could provide solutions. Stone's example of cassava is appropriate, but a similar situation exists for a large number of crops that could provide viable alternatives to cereal crops. Dryland crops would require involved breeding programmes that combine genetic engineering with conventional breeding to increase and stabilize yield by building resistance to a large number of biotic stresses.

One of Stone's major suggestions is supporting public research on genetically modified crops. This is the "middle ground," and I fully agree with the prescription. Stone has rightly pointed out that the overzealous negativism of the greens could drive public research completely into the orbit of industry. However, for the "middle-ground" approach to succeed, more resolute action is required at both the national and the international level.

A major impediment to effective public research on genetically modified crops stems from the overzealous patenting of gene sequences. Breeding of crops, particularly those that are relevant to developing countries, requires multiple genetic inputs—promoters, genes, vectors, transformation protocols, germplasm, and varieties that have been specifically bred for dryland, low-input conditions. Much of the research on genes, vectors, and breeding (particularly of self-pollinated crops) has been done in the public system. In handing over all this research to the multinationals for the global spread of genetically modified crops we are making a policy blunder. The rich (developed countries) can do without genetic-modification technologies (at least for the present); the poor need them but may not be able to afford them, and developing countries may end up subsidizing genetically modified seeds in addition to electricity and fertilizers, thereby imposing a further drain on their economies.

If we care about the small farmers of developing countries and would like to help them towards a reasonable life, we will have to perceive gene sequences in the same way as we perceived germplasm years ago—as a shared heritage of humankind. The North benefited from the germplasm; let the South benefit from the genes. If this old-fashioned liberal and caring view is seriously considered and the CGIAR system and collaborative research are strengthened, the dividends will be high for both developed and developing countries. Stone's "middle ground" is the appropriate stance on genetically modified crop research and the eventual deployment of genetically modified crops in farmers' fields, but exploitation of this "middle ground" will require sagacity and fresh and innovative approaches towards the organization of global and national agricultural research programmes.

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Stone calls for a greater involvement by anthropologists in biotechnology assessment. A problem is that the discipline is, at heart, much less normatively oriented than economics, its obvious rival in this area. Long and Long (1992) make clear that the role of the anthropologist in rural development is to document struggle over development interventions, not to intervene directly. Nor has anthropology had much apparent impact on technology assessment in the North. A British method known as technology foresight studies tends to be based on negotiations between engineers and other experts and government. The Dutch "back-casting" method is better at incorporating societal interests but, even so, perhaps makes less use than it might of the social studies of technology in which Dutch universities excel. The relative absence of anthropologists from technology forecasting needs to be examined before we jump to the conclusion that the field of biotechnology awaits our contribution.

Trained to recognize norms, anthropologists are perhaps averse to elaborating their own preferences in regard to the future. And yet this objection of conscience seems to be specific to technology. Anthropologists are apparently much more willing to "muck in" when it comes to medical subjects, human rights, or conflict resolution, all of which are as future-oriented and value-laden as technology assessment. Is there perhaps an ingrained distaste in the discipline for technology itself?

Ingold (1999) notes that "technology" as concept emerges from a rather specific history of struggle over labour and property rights. He suggests that if the anthropology of technology is fully to develop it will first have to reverse the separation of people and machine that has served capitalist interests for several centuries. A way forward is to recognize that all technique is human instrumentality. Ingold, in effect, provides a theoretical justification for what has been the main thrust of anthropologically oriented studies of technology—the practice paradigm.

Practice studies have provided a powerful framework within which to examine agricultural and food production activities and even the practices of the life sciences themselves (Hardin 1993, Nyerges 1997, Knorr-Cetina 1999), but there are some areas associated with the assessment of genetically modified crops in which we are still almost entirely in the dark. It has for some years been clear that gene flow might pose problems to the use of genetically modified organisms. Safety protocols are only as good as knowledge of the processes involved. Many aspects of gene flow in agricultural crops are influenced by the practices of agriculture, including social aspects of seed distribution. Stone offers a case in point when he wonders about genetically modified tomato seeds "smuggled" into Mexico by returning migrant workers.

Some anthropologists have attempted to specify the social life of seeds (Richards 1986, Longley 2000, Zimmerer 1996), but few such studies fully incorporate molecular marker data (cf. Dennis 1987). That surprises may be in store is suggested by a study claiming to have located transgenic constructs in isolated farmer-managed land-race populations of maize in highland Mexico (Quist and Chapela 2001, but cf. Butler 2002). Clearly, then, Stone is right—anthropologists have work to do in contributing to fuller knowledge of relevant practices, especially those affecting gene flow. Such studies will be especially important if public-interest, not-for-profit biotechnologies such as facultative apomixis assume importance in the South. In the apomixis case, understanding social seed systems will assume special relevance in debates about "cutting off" natural out-crossing among crop types that feeds farmers' varietal selection processes (cf. Almekinders and Elings 2001, Richards 1995, Jusu 1999), but anthropologists will need more than practice studies if they are to play a less marginal role in technology assessment. As critics of "applied anthropology" frequently point out, the discipline needs a way to address issues of how power is made.

Here it may be as important to pursue the emphasis of Peel (1995) on narrative as to assume a practice-oriented approach. Storytelling remains one of the most powerful ways of creating temporal coherence among imagined or experienced events. Every research proposal is such a narrative performance. Not only must past work be reviewed and assessed and expected outcomes specified but the work plan itself has to be laid out as coherent timetable of planned events. Examining the narrative form of research proposals is but one obvious way in which anthropologists could contribute to understanding of how technological futures are constructed.

Any such work would also bring out the importance of other narratives, especially those that contest the assumptions of the market-led life sciences. Wakeford's (2000) recent work with Indian farmers on biotechnology futures is an example. The logistics of any such consultation appears daunting, if true grassroots democracy is intended. The interests of 2 billion peasants may be far too diverse to arrive at consensual views. The anthropologist may find it more feasible and as valuable to concentrate on detecting, documenting, and linking up some of the social movements of plebeian science that have always made fieldwork among peasants such an exciting experience (Archibald and Richards n.d., Barrow 1986, Richards 1985).

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Stone makes a case for an anthropological approach to the issues surrounding genetic modification and food security in developing countries. The profiles of the two sides that he provides are, of course, interesting, but they are not comprehensive. One major shortcoming of studies of these issues is that they are not based on an understanding of the dynamics of the institutional changes accompanying any such radical technological or crop revolution, and the same shortcoming may well apply to the anthropological approach. Let me illustrate this with reference to the Green Revolution and the apparent paradox of mounting food-grain stocks with declining food-grain intake in rural India.

The Green Revolution has undoubtedly played an important role in sustaining the growth in food-grain production in India, but has this resulted in increased food security? The answer is yes if one adopts simple measures such as per capita availability and imports as a percentage of domestic availability, and India is widely believed to have achieved food security. Simple summary statistics can, however, be misleading. Has the Green Revolution in India led to a corresponding increase in food-grain consumption and nutritional intake for the population, the poor in particular? The answer is no.

The Green Revolution has led to substantial changes in the crop composition of output and the labour and commodity markets. As regards crops, it has benefited largely wheat and rice; the crop composition of food grains has changed in favor of these superior cereals because of considerations of cost, relative profitability, and rate of return. As a result, the area under coarse cereals, which had increased at the rate of 0.87% per annum from 1949–50 to 1964–65, declined at a rate of 1.20% per annum from 1967–68 to 1993–94, while the area under the superior cereals increased throughout this period. Between 1960–61 and 1993–94 per capita daily availability of rice increased from 201.1 g to 207.4 g (by 3.13%) and that of wheat from 79.1 g to 159.5 g (by 101.64%) while that of other cereals decreased from 119.5 g to 67.1 g (by 43.85%). Poor subsistence farmers used to grow and consume largely the cheaper but more nutritious coarse cereals, but in the wake of the Green Revolution they have no option but to shift their cereal consumption in favor of superior but costlier cereals. This has increased their market dependence on the costlier rice and wheat.

At the same time, for a variety of reasons including demographic pressure, urbanization, industrialization, and modernization, both input and output markets have been undergoing substantial change, and this change along with increasing landlessness and the casualization of rural labour has only reinforced the market dependence of the poor on the superior cereals. Other types of rural households have had to change their preferences because of the decline in coarse cereal availability. The reduction in availability of coarse cereals has involved an increase in the average cost of cereals, affecting the portion of total consumption that is met through market purchases. This has led to a decline in total cereal consumption in spite of an apparent increase in estimates of real consumer expenditure for the poorer sections in the rural areas. Consumer expenditure for the richer sections has either stagnated or declined marginally, and even for these groups the increase in the average cost of the cereal basket has affected cereal consumption adversely. Thus, with bulging food-grain stocks, actual food and calorie consumption has been declining in rural India.

A genetic-modification revolution would also be accompanied by dynamic institutional changes in the developing countries. The limited scope for recycling crops alone would lead to radical changes in production relations and cost conditions, not to mention the negative externalities associated with the monopolistic behavior of actors such as Monsanto. Unless such dynamic changes are taken into account, estimates of the costs and benefits associated with the genetic-modification revolution may not lead to a fair assessment of its real-life consequences for developing countries.

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Stone's paper performs an important service by drawing attention to the exceptionally low quality of arguments on both sides of the debate about biotechnology and developing countries.

It is correct that a crude Malthusian logic cannot justify support for biotechnology and that biotechnology's champions give insufficient attention to the line between agricultural innovation and poverty reduction. The Indian example is instructive, showing that increased agricultural production, on its own, does not address the entitlement issue, but Stone's emphasis on Indian "overproduction" is misleading. India can be judged to overproduce only in reference to grain-marketing opportunities, which include exports. India currently exports a significant amount of rice (Datta 2001). Indeed, the recent attempt by a Texas company to obtain broad patents on Basmati rice varieties (one of the anti-genetic-modification lobby's favorite examples of the dangers of plant patents) is important principally because of the potential threat to India's (and Pakistan's) rice *export* markets. The problems noted by Stone are caused by inadequate grain-marketing systems, ill-conceived input subsidies, and inappropriate food security policies. When the subsidies are removed (and the savings are applied to rural development priorities), India will need technology that improves farmers' efficiency and conserves resources. Biotechnology might play an important role, but the point is well taken that no technology is going to address the broader policy questions.

Stone also usefully points out that biotechnology's critics studiously avoid reference to the considerable amount of public research devoted to pro-poor biotechnology development. The green lobby ignores public research partly because it spoils its just-so story of evil corporations exploiting traditional farmers but also because many of the NGOs leading the anti-genetic-modification campaign compete for public agricultural development funds. However, such competition is not the only reason that public agricultural research is in disarray (Tripp n.d.). If public research is to fulfil the promise Stone suggests, significant reorientation and support will be required.

How might public research in agricultural technology be directed towards poverty reduction? One of Stone's suggestions for an appropriate target, cassava, has potential for pro-poor biotechnology research not because it is vegetatively propagated but because of its important place in smallholder farming. Plant variety protection is not limited to seeds; for instance, the U.S. Plant Patent Act of 1930 focused exclusively on asexually propagated species (Kloppenburg 1988). Cassava survives (rather than "thrives") on poor soils and moisture, which helps explain the large gap between actual and potential yields, but the tools of biotechnology (with or without genetic modification) can certainly bring improvements. The argument that rain-fed crops (such as sorghum and millet) are particularly appropriate candidates must be validated in specific farming systems. The relative decline in their production in India is a product of irrigation availability, consumer preferences, and the opportunities for growing alternative crops, but these factors are not of recent origin (e.g., Reddy 1987). Part of the problem is a confusion in the paper between "subsistence crops" and crops that are important for the poor. Cassava is introduced as a subsistence crop, but its cash-crop potential is also acknowledged; rice is initially rejected for consideration but later described as a subsistence crop (which it is in many cases). There are many crops that are possible targets for biotechnology. Even the rice and wheat that currently fill government warehouses in India would be logical examples because of the large numbers of poor producers and consumers that depend on them. The challenge is to identify how production changes in specific farming systems are likely to affect the poor. The detailed empirical data that anthropologists are capable of providing can make invaluable contributions to these decisions.

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Stone's study of the political firestorm ignited by genetically modified food production is an appropriate start for 21st-century ethnography. After nearly 20 years of avoidance, anthropologists are focusing (again) on primary production and the complexities of global capitalism. Where better to start than with the technological changes that have transformed modern agriculture?

Why have American anthropologists ignored their own backyard, the vast corn–soybean–wheat belt in the center of our country? (There are, happily, some notable exceptions [see Stone's bibliography].) Our students, even those who grew up in Des Moines and Duluth, know almost nothing about modern agriculture. Last year, after viewing slides of genetically modified (Bt) corn production, several undergraduates in my Food and Culture course expressed surprise to learn that maize grows on stalks rather than ground-hugging vines. Another student did not know that potatoes are root crops: "You mean they grow underground? I always thought they grew on bushes." Given the fact that this student had spent his first 18 years in New York City we might be tempted to excuse him. Colleagues at the University of Nebraska, Oberlin College, and the University of Georgia report similar encounters.

How did we get to this point? Should we worry about it? Or should we celebrate our retreat from primary production as evidence that anthropology has moved with the times and reflects the postmodernism of everyday life?

Stone reminds us that we do not live by text alone. We also eat, and a high percentage of the American diet contains transgenic grain by-products. Furthermore, the controversy surrounding this revolution in food production is directly linked (hyperlinked) to the antiglobalization movements that preoccupy many of our students. If anthropologists do not venture into this research arena, other "culture specialists" will certainly do so.

One need only hit the "genetic modification" button on Yahoo's food page to enter a cyber-world of flaming rhetoric and urban legend. No amount of scientific evidence will kill the monarch butterfly legend or the StarLink allergy stories. Stone only hints at the dynamism and technological sophistication of global antiglobalization movements. One can surf seamlessly from anti-genetic-modification food sites to anti-McDonald's sites to animal rights sites and back again in a never-ending, self-perpetuating chain. Students in my Food and Culture course have tracked literally thousands of anticorporate "food alarm" sites. This obsession with dietary purity and the politics of eating has become the equivalent of religion for many young people in advanced capitalist societies. Some spend more time engaged with like-minded counterparts in the virtual world of Web communities than they do with friends in the "real" world of dorms, bars, and classes. This is rich ground for ethnographic analysis.

To Stone's three suggested avenues for future research I would add research on the reception/rejection and consumption of genetically modified foods. Responses to the genetic modification revolution vary widely. A transnational team of anthropologists based at Harvard is currently working on genetically modified (Round-up Ready) soybean production in Henry Country, Illinois, and the consumption of American beans in China, Japan, Korea, and Taiwan. We have, to date, found widely differing responses—from outright rejection in Japan to near indifference in Taiwan. Meanwhile China is pushing its own biotech revolution and creating new genetically modified crops, while keeping American genetically modified grain at arm's length. Stone's work in India provides another perspective (witness the recent news of India's acceptance of Bt cotton). More work needs to be done in Europe, especially in France and Britain, where in the aftermath of the Mad Cow fiasco anti-genetic-modification sentiment is a hot political issue.

Stone's writings should be required reading for all graduate students who look to the future of anthropology rather than its past.

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Stone's paper attempts to do three connected things: provide a broader perspective on what he criticizes as falsely polarized discourses about genetically modified agriculture's benefits and risks, expose the selective representations of both "sides" of this discursive polarization, and finally, having included some academic work in this "false polarization" critique, offer some proposals as to the more constructive role which anthropology could play in the attempt to achieve a more discriminating and conditional approach to the development and practical exploitation of genetic modification science.

A premise of his account is the belief that both sides have switched reference from the developed to the developing world as an alternative tactical object to further their campaigns for or against genetically modified crops. This is a more or less historical claim that such a switch of focus has recently occurred as a tactical-rhetorical move to outflank the opposition in what is still a rich-world stalemate by morally enrolling the poor and the starving in less developed countries. Stone's point, well-made, is that these rhetorical constructions bear no defensible relationship to the observable realities and therefore systematically corrupt public debate and decision making.

I start from a basic sympathy with Stone's overall aim, namely, to develop a richer, more discriminating and more realistic public discourse (including practice) of genetic-modification science and technology. As a non-anthropologist I also share his view that anthropology has important contributions to make which are not reflected in the dominant forms of discourse. Although the paper raises many substantive issues and connections, because of the limits of space I here focus on two connected questions only.

I want first to raise questions about his premise that the focus on the developing world is only a tactical move. An interest—which Stone neglects—in public perceptions and meanings as well as in protagonists' discursive constructions puts a different perspective on this without wholly refuting the "tactical" interpretation. This different angle of approach also raises deeper questions about the presumed nature of public reactions to this technology, its forms of promotion and opposition, and its possible consequences. The by-default implication of Stone's paper is that public reactions merely follow actors' discursive framings (lining up with one "side" or the other), but I want to argue that this relationship is much more complex and those public reactions and meanings—whether in the developed or the developing world—more independent (e.g., Scott 1994).

One place where this independence has been found (Wynne et al. 2001) is in public reactions to scientific discourses of risk, which straddle developed and developing world contexts indiscriminately, with no significant differences in basic form. Here it has been suggested from empirical research on public attitudes to genetically modified crops that a central issue for people is not so much risk (that is, the *known* consequences on which scientific risk assessments and related scientific reassurances focus) as the institutional scientific and policy neglect of *unknown* consequences. Institutions, in other words, are routinely presuming to know the meaning of such issues and imposing this on the public. People also link this independently framed concern about not only "risks" but unknowns (which are in effect denied by the institutional focus on risk) with that over whose purposes and interests are driving genetic-modification R&D and commercial innovation. If unpredictable, unknown consequences will occur, they say, what this means is not that we should close down genetic-modification science and technology (this being recognized to be a universal predicament) but that we should be much more careful about whose purposes are driving it all. Here, at least in typical European settings, they do not find reassurance, since, as they see it, private commercial interests are in control—indeed, increasingly so—and no sign of any sense of public interest influences the key drivers of the science, let alone the dominant commercial trajectories. Maybe there is a difference here between typical European and U.S. publics—though recent U.S. research also indicates an independent public framework of meaning in relation to institutional scientific risk assessment (Levy and Darby 2000). My key point, however, is that, while its positive aspects should not be ignored, the essentially interests-based social science paradigm which highlights what is seen as a tactical-rhetorical switch to developing-country genetically modified crop and food arguments has limitations. Thus, for example, it completely ignores questions about how such protagonists' discourses and practices (not only rhetorical) relate to a wider public culture and its globally differentiated, diversely embodied, independent frameworks of meaning and reaction (Action Aid 2001).

The political-economic questions about the formation and power of global scientific-technical-commercial networks and their associated regulatory networks and the public-private influence issues which pervade these as well as public concerns require both empirical and conceptual social scientific work, as is indirectly suggested by Stone's treatment of the corresponding rhetorical outputs and strategies. However, and crucially, this political-economic research and reflection needs to be combined with a cultural understanding of diverse global public experiences and knowledges of and responses to these powerful networks and their discourses—cultural insight which is the bread-and-butter of anthropology. Even further, however, anthropology has a key role to play in gaining insight into how these powerful scientific-technical networks are shaped, institutionalized, contextually embedded, and encultured in the anthropological sense of becoming taken-for-granted and "natural" to their social actors as systems of power which nevertheless could be different (as in Stone's point about the different kinds of genetically modified agriculture that would likely emerge from "private" or "public" control of R&D).

Stone's paper does not fully succeed in the task of opening up these issues—not surprisingly, perhaps, given their complexity and scale. However, it does do a valuable job of identifying some important lacunae and systematic biases in dominant discourses of the issues, and this is essential ground-clearing for the bigger challenges which lie ahead.

Reply

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I am grateful for commentary from this varied and important group of scholars. I regret only the absence of an advocate for the Malthusian position, as I was curious how it might be defended against the facts on the food situation in India. I was also curious how the green view of genetic modification as a monolithic threat to developing countries might be defended against the case that it blurs important differences between the offerings of corporate and public biotechnology projects (other than the overhyped Golden Rice). I regret that Altieri fails to engage this point, reverting instead to stock criticisms of Golden Rice.

I do appreciate Altieri's challenge to political neutrality and agree that ostensibly neutral scholarship may have unintended political consequences. The problem is how one chooses a nonneutral position: How does one decide which side to take in this polarized debate or to develop a perspective independent of the poles? With Richards, I worry about anthropologists' being guided by an a priori aversion to technology; this would be blinkered indeed where the technology is so multifaceted and changeable. Choosing a position demands an ongoing analysis rather than a one-off assessment. The first step in such an analysis is to look discriminatingly at biotechnology, and this means defying the shared industry and green strategy of blurring the boundaries (a strategy that Altieri obligingly demonstrates as he tilts at the monolithic bogeyman of biotechnology).

I am also concerned about how this abandonment of neutrality affects the practice of science. Does it commit one to rejecting any positive findings on genetic modification? If so, does this not taint any claims to a scientific basis for analysis? This stance is no better than the genetic-modification proponents' claiming a "science-based" rather than a "fear-based" approach while accepting unpublished industry claims over inconvenient findings in refereed scientific journals and provoking fear of food shortages on the basis of misinformation.

Altieri recognizes the need for empirical observation and analysis; he supports his own position with empirical claims, presented as objective. Yet I must point out that they are not entirely accurate. He claims that genetically modified yields are lower in soybeans and unchanged in cotton. It is true that there is a small yield drag in soybeans (Benbrook 2001), but cotton yields to date are somewhat higher in areas with heavy predation by Bt-sensitive lepidopterans (which is where adoption rates are high). This applies not only in the United States (Economic Research Service 2001) but in the developing countries of China (Pray et al. 2000), Mexico (Traxler et al. 2001), and South Africa (Bennett et al. n.d., Ismael, Bennett, and Morse 2001). But it is easy to attach too much importance to short-term crop yields. India's grain situation makes this point tragically well, and I have argued (Stone 2002*a*) that India also has reason to be wary of the overall effects of genetically modified cotton on rural society and sustainability.

Altieri also claims that savings on insecticides are insignificant compared with savings from integrated pest management. This is an overgeneralization and an overstatement; for instance, it is certainly not supported by the cotton studies cited above. Yet there are good grounds for concluding that integrated pest management holds much greater promise for agricultural sustainability than genetically modified crops in general, and I am skeptical of industry claims that genetically modified crops are consistent with it (Council for Biotechnology Information 2001). One reason is that "self-learning" is vital for sustainable agriculture (Pretty and Ward 2001:217), and genetically modified crops may well prove to be agents of deskilling. However, as I have noted, this is a topic for research rather than an established fact.

Are there really no biotechnological breakthroughs to boost yields of resource-poor farmers on the horizon? Xa21 rice, genetically modified at ILTAB for resistance to bacterial blight, has been field-tested over seven generations in China and may be released soon. But it is quite true that very little of what genetic modification has to offer poor farmers has yet been realized. My examples of cassava and apomixis will offer no benefits for years, and there is no guarantee that they will ever be implemented so as to favor resource-poor farmers and sustainability. The job of steering research and development toward pro-poor technologies is difficult but crucial. Indeed, given the corporate domination of the technology, the government support of the corporate agenda, and the push toward international harmonization of intellectual property rights, the task sometimes seems sisyphean. Leading agroecologists like Altieri would have more positive effect by contributing to this effort than by maintaining the studiously naive position that all biotechnology is cut from the same evil cloth.

The anthropologist Tripp, the economist Suryanarayana, and the biologist Pental all help to broaden the India case study. However, Tripp misses the point about India's buffer stocks: these are intended for food security rather than export, and the colossal overstock is being released to private traders only because it would otherwise rot. The overstock of 41.2 million tons of rice and wheat is indeed overproduction; in part a perverse byproduct of the Green Revolution, which was itself in part a result of U.S. overproduction, it is extremely costly for India (to my discussion of costs, Suryanarayana adds an explanation of how the shift to these "superior" cereals has led to reduced cereal consumption even as yields climbed). The overpriced surplus is one source of India's rice exports, which have included even more non-Basmati than Basmati over the past two years.[1] India's exporting of grain while so many Indians go hungry rein-

1. Between April 1999 and March 2001, India exported 1.5 million tons of Basmati rice and 1.9 tons of non-Basmati rice (Indian Ministry of Agriculture, http://agricoop.nic.in/statistics/impexp6.htm).

forces my criticism of the Malthusian justifications for genetic modification.

Tripp raises an interesting issue with his suggestion that biotechnology will increase agricultural efficiency once India removes farm subsidies. Industrialized countries are not so much removing subsidies as changing their nature, favoring more indirect means of underwriting. Heavy subsidy of crop biotechnology research is an example. The U.S. government spends around a quarter billion dollars a year on biotechnology research, developing such projects as the "Terminator," and underwrites (mainly corporate) biotechnology in numerous other ways. If efficiency refers to output : input ratios, then the increasing importance of these indirect inputs must be included in the equation, showing genetically modified agriculture to be less efficient than it appears on the surface. India will have to subsidize genetically modified crops as well (as Pental notes), although developed countries may help foot the bill. It is claimed that Britain has pledged £65 million to Andhra Pradesh's Vision 20/20—a program for replacing intensive smallholder farms with large-scale industrial monocultures including genetically modified crops (Monbiot 2002). This figure may be an exaggeration, but it is worth noting that it is four times the annual budget of the ICRISAT, which is pursuing pro-poor genetic modification.

Thus Tripp and Pental are right that public biotechnology needs more support, but what kind of "reorientation" it will take to get support is the problem. The trend is toward increasingly close links with industry, which has the money and the patents. What will public labs have to provide in return? It will be more than grist for the industry PR mill; research agendas are also in the balance. Also troubling is the relative invisibility of the effects of corporate sponsorship. For instance, apomixis research is now partly supported by corporate funding at the International Center for the Improvement of Maize and Wheat (CIMMYT), but there has been little scrutiny of this arrangement. The problem is not only industry and green boundary-blurring but also corporate confidentiality agreements.

The choosing of directions for research and development remains something of a black box, but the choices are crucial. Nutritional enhancement of cassava is only one of many examples of potentially fruitful public research, but I think it will be an important one, and I welcome debate on its merits from researchers such as Tripp. We agree that cassava is important primarily because of its role in smallholder farming, but I disagree that cassava's vegetative propagation will not affect its utility for the poor. Tripp is correct that vegetatively propagating plants can be patented, but even the U.S. Plant Protection Act, in the country with world's the strongest plant intellectual property controls, did not prohibit farmers from replanting, giving, or even selling crops to other farmers, and it will be difficult to prevent farmers in the developing world from planting cassava cuttings. In contrast, the replanting of seed crops is easier to block by the use of hybrids or genetic use-restriction technologies. This vegetative reproduction is both a blessing and a curse. Its hindrance of commodification is one reason for the relative lack of cassava research, but if the crop can be genetically modified through public research, perhaps farmers will have the best of both worlds.

Most commentators engage the question of what anthropology's intervention in the biotechnology issue can and should be. This article is itself one form of anthropological intervention: contextualizing the shift in rhetoric to the developing world, analyzing the structure of the discourse, and contrasting fallacies from both sides with some empirical material from the front-line country of India. Wynne is right that it is more of a summary examination of discourse and that discourse is formulated in very different ways that reflect the global picture. For instance, media coverage of Third World hunger has been mainly confined to the United States—ironically, the place in which genetically modified crops seem most safely entrenched; this is largely an attempt to avert a backlash such as occurred in Europe. How global: transnational companies responding to European backlash by telling Americans that biotechnology will feed the Third World. This campaign's Malthusian metanarrative is also adapted to the United States, where Malthus's transplanted roots have grown deepest (see Ross 1998). Malthus's preoccupation with intrasocietal differences is replaced by a First-versus-Third-World contrast; the last thing today's Malthusians want to publicize is the 31 million food-insecure people in America, where genetically modified crops are widely grown (Economic Research Service 2000). Malthus's fatalistic view of the inevitability of starvation is replaced by a promise of averting hunger through technology provided that it is profitable for corporations (Stone 2002*b*).

In Britain, pro-genetic-modification rhetoric has been muted since Monsanto's disastrous late-1990s campaign, with little more than occasional rants against Britain's organic-food boom. This will change, and the content and effect of the next round of industry rhetoric will be interesting to see. One assumes that industry will have learned that cultural notions of potential benefits and danger are deeply embedded and complex; Wynne is right that the public may maintain concepts of unknown consequences that are not reflected at all in official approaches to risk assessment (although this is hardly at odds with my analysis of discursive strategies). As Levidow (1995:182) argues, decisions on what kinds of direct and indirect effects can and should be considered are partly cultural and ethical, despite government claims of their separability.

Anthropology's most enduring contributions, however, will come from studying not discourse but culture and agriculture, and to my quick sketches of research topics the commentators make valuable additions. The Watson team's comparative study of crop biotechnology in Asia (plus the American corn belt) will be invaluable, and if Watson's (1997) work on McDonald's in Asia is any guide, there will be interesting findings on how genetically modified crops and foods are indigenized. I could not agree more on the importance of studying genetically modified crops in the context of agricultural *practice* that Richards emphasizes, and Richards's own work here (e.g., on the reception of different kinds of modern rice varieties by Sierra Leonean farmers [Richards 1997]) is exemplary. Our "rival" in such research—in the professional literature anyway—is not economics per se but narrowly limited work on short-term immediate costs and returns such as the cotton studies cited above (several of which are by economists). While these assessments serve a useful function, they capture only one component of change and can detract attention from the subtle institutional changes that Suryanarayana rightly stresses.

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