The Genomics Revolution and Development Studies: Science, Politics and Poverty

Ronald J. Herring

Promethean Science, Pandora's Jug

The intersection of technological change, human progress, and threats to vulnerable populations is the locus of classic controversies in development studies. Ned Ludd contributed his name to one hostile characterization of opponents of technical change, but raised the critical developmental question: whatever some notional aggregate cost-benefit ratio indicates, there is a socially charged question of disaggregation: whose benefits and whose costs?

The genomics revolution in biology resonates with previous contestations of technical change, but has raised genuinely new problematics: property claims and novel organisms unimaginable a generation ago, with implications for human health, food production, trade regimes and environmental integrity. In medical applications, genetic engineering based on recombinant DNA technologies has brought mostly quiescent or appreciative responses from mass publics. Neither diabetic patients nor their physicians typically resist synthetic human insulin, for example, though it has been produced by genetically engineered organisms since 1978. Transgenics in the pharmaceutical sector have been largely immune to mass mobilization; as with insulin, life-saving is widely accepted as a legitimate trade-off for uncertainty – or, at a minimum, a political reason to focus mobilization efforts elsewhere (Lezaun 2004). Yet in agriculture and food systems conflicts are dramatic: field trials of crops are burned, experimental stations are attacked, a remarkable transcontinental caravan of farmers travels from India to Europe to protest the global power of multinationals controlling "GMOs" (Madsen 2001). A sense of the scope of this global dispute can be gleaned from recent titles of books on biotechnology: **Gene Wars**; **Pandora's Picnic Basket**; **Lords of the Harvest**; **Politics of Precaution**; **Seeds of Suicide**.[1]

Science is the fulcrum on which this contentious politics rests. Science as agnostic method for adjudicating truth claims in applied genomics is overwhelmed by a politicized science constructed as either target or legitimation in strategies of corporations, government agencies, evangelical politicians, social movements and NGOs. Science becomes less method than arena. Applied biological science surprises its practitioners as appearing not as mode of inquiry, but as locus of contests around national sovereignty, international power relations, neocolonial dominance. "Junk science" is perhaps the most common epithet hurled at Vandana Shiva -- the leading Pandoran -- who answers in turn with charges of "imperialist science." "Western science" as derogatory identifies a logic of inquiry that claims for itself no geography (Nanda 2003: 125-181). It is not, as pro-biotechnology forces often charge, a contest between Science and Luddism. Science does

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[1] Respectively, Dawkins l997; McHughen 2000; Charles 2001; Paarlberg, 2001; Shiva et al 2000. On the global division on transgenics, see also Winston, 2002; Pinstrup-Anderson and Ebbe Schioler, 2000; Shiva 2000.

not presume to answer questions in normative theory, nor risk preferences. Moreover there are organizations of scientists deeply troubled by genetically engineered organisms.[2] There are also specifiable "known unknowns" – allergenicity from novel proteins, horizontal gene flow -- and almost certainly "unknown unknowns" as well, to recognize the epistemological epiphany of Donald Rumsfeld on weapons of mass destruction.

In the biotechnology[3] debate, science is sometimes qualified by the adjective **"Promethean."** This qualification defines a normative stance: that there are risks -- as with the mythical gift of fire from Prometheus to humans -- but also the potential for great good achievable in no other way.[4] In granting fire to humans, Prometheus understood that it would confer novel powers and comforts to the species, but also new hazards for humans and other species. Opponents of genetic engineering argue that we are dealing not with Promethean promise and controllable risk, but with Pandora's jug, with correspondingly darker connotations. Pandora was in Greek mythology the first woman on earth, given by Zeus to Epimethus, brother of Prometheus; Prometheus and Pandora were related from the beginning. Pandora came with a sealed jug -- or box in some tellings -- that was not to be opened. Opening the jug released all evils that afflict the human species. Pandora's lesson is that unanticipated consequences of a characteristic human trait – curiosity – may be catastrophic. Inquisitive behavior beyond some limits is proscribed; in criticisms of biotechnology, the creation of organisms nature cannot make is called "playing God," with severe precautionary implications. The global debate reproduces the cleavages introduced by Prometheus and Pandora. A great wall has emerged between camps that believe the biological revolution is more like fire – a source of human progress, entailing risks but amenable to control if used wisely – and those who believe we confront Pandora's jug, set to unleash unknown, perhaps unimagined, evils on our species and others: from ecological disaster to bioterrorism.[5] Divergent claims to

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[2] For example, The Union of Concerned Scientists in the United States and the Independent Science Panel in the UK, both of which maintain considerable listings of science that casts doubt on biotechnology. See e.g. the ISP report by Ho and Ching 2003.
[3] When political opponents use the term, they usually mean recombinant DNA technology -- the transfer of DNA across species lines. Contemporary biotechnology covers a much broader terrain than genetic engineering, including such techniques as tissue culture and marker-aided selection. Defined as the use of living organisms or their products for commercial purposes, biotechnology begins at least as early as written history in brewing beverages and making bread.

[4] Serageldin and Persley 2000; see also Dryzek 1997. Politics mobilized to contest the unnatural nature of biotechnology perhaps unknowingly reproduce -- through references to *Frankenfoods* and even *Frankenpants* (made from Bt cotton) -- the original Promethean connection established by the inventor of the monster. Mary Wollstonecraft Shelley subtitled her 1818 classic **Frankenstein** "*The Modern Prometheus*."

[5] Deadly anthrax attacks in the United States in 2001 – still unsolved -- spawned a round of debates on genetic engineering as the source of new risks represented by bioterrorism.

knowledge reflect and justify widely varying, socially conditioned distributions of risk aversion and risk acceptance (Douglas and Wildavsky 1982). Most North Americans consume transgenic foods with little thought of allergenicity; Europeans – and some in Asian societies – reject that risk (Plotkin 2000). Zambia and Zimbabwe in 2002 rejected United Nations food aid containing some transgenic maize kernels in the midst of famine, terming the shipment "poison."[6] The poison in question is corn American parents feed their children routinely. It is hard to exaggerate this cognitive chasm.

New confrontations have not followed familiar North-South tectonics. Among the leaders in genetically engineered crops are China and Argentina, along with the United States and Canada. Significant opposition has arisen in Europe and some African nations, and in metropolitan South Asia. Yet there is growing evidence that farmers seek out, grow and cross transgenic varieties their governments officially proscribe. Divisions reflect genuinely new developmental dilemmas. Poor nations could consider their interests threatened by a global technological revolution that undermines both exports and farm income. This consideration was quite explicit in Brazil's early attempt to compete with the United States and Argentina by adopting transgenic soy. In New Delhi, the cliché one hears is: "we missed the industrial revolution, we cannot afford to miss the information revolution." From this reading of national interest, the very existence of biotechnology puts pressure on the developmental state to make new choices.[7] Nations at the bottom of the global economic hierarchy could, however, and sometimes do, see the technological change embodied in genetic engineering as a new dependency trap – or a risk to exports to Europe and Japan -- rather than a source of new opportunities.

Poverty has figured prominently in conflicts over the place of genetic engineering in development strategy. India's then-Prime Minister Atal Bihari Vajpayee sketched the pro-poor developmentalist state version as a "vision of shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor." Biotechnology is to fight obdurate diseases, increase agricultural production, combat nutritional deficiencies and protect the environment. Any and all of these outcomes could be pro-poor if realized. But articulate civil society in India has written more frequently of "seeds of death."[8] Both supporters and opponents of transgenics have a poverty story to tell. Proponents have resurrected the Reverend Malthus in a view of aggregate food security that is often global: "feeding a hungry world" is the corporate expression. Per Pinstrup-Andersen and Ebbe Schioler, in a

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See Vandana Shiva's comments from **The Hindu**, <http//www.hinduonnet.com/stories/0519134i.htm>

[6] **Scientific American** August 2004, Vol. 291, Issue 2, p8. The UNFAO, in its 2003-2004 State of Food and Agriculture warned that the "war of rhetoric" might be more dangerous for small farmers than the transgenics themselves. This bizarre construction of saving the starving from "poison" is almost certainly motivated by concern about European markets for agricultural products more than welfare of poor people.
[7] Paarlberg 2001: 6-8 and chapter 4; On developmental state theory, Woo 1999.
[8] Department of Biotechnology 2001; Shiva et al, 2000; Herring, "Miracle Seeds, Suicide Seeds…" 2005.

book that won the World Food Prize for 2001, conclude that "once again Malthus's clash between population growth and food production looms threateningly on the horizon."[9] Proponents emphasize aggregate food availability, and center on small farmers as the poor. Both perspectives require significant disaggregation.

In the optimistic scenario, expanding the production possibilities frontier of transgenic crops offers special advantages to the poor because food scarcity prices poor consumers out of the market. For poor producers, seeds represent a completely divisible technology; in theory, this seed revolution should be scale-neutral. Scale neutrality may extend to alleviating certain financial vulnerabilities of the small farm: some transgenic seeds, such as those containing a gene from the common soil bacterium *Bacillus thuringiensis* – hence the "Bt" designation -- substitute a plant's own biological processes for cash-intensive inputs such as pesticides, as explored by Tony Shelton in this volume. Cash-intensive inputs differentiate farmers along lines of wealth; bad harvests may produce crippling debt through such intermediaries as pesticide merchants, as was evident in the epidemic of farmer suicides in India in l998.[10] Being strapped for cash, and typically less able to tap inexpensive sources of credit through social standing or political connections, the poor farmer is especially interested in reduction of upfront cash expenditures. If the technology works, the question then turns to the price of the seeds, and thus on the intellectual property contained therein.[11]

Opponents argue that it is precisely the most vulnerable sections of the population that will be put most at risk, and often begin with intellectual property. Specifically, biotechnology enables new possibilities for monopoly control of genetic materials and thus of pricing and access, as well as global bio-piracy that plunders genetic resources of indigenous peoples and poor nations to make corporate property (Shiva 2001). The poor farmer, in this view, will be crushed by bondage to multinational monopolists, subordinating poor farmers to neo-colonial control. The most excoriated mechanism has been "terminator technology," widely charged to Monsanto, the lightening rod of protest globally. Critics also see the poor as subjected to special risk of environmental degradation, unsafe foods introduced via foreign aid or public distribution systems, or allergenicity from novel proteins (Shiva 1997; 2000; Altieri 2001; Winston 2002).

What unites the authors in this volume – scientists and social scientists alike -- is the conviction that these questions are of great consequence and are amenable to empirical treatment, common practice notwithstanding. We believe that being wrong about transgenics could have adverse consequences for the poor -- both poor nations and

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[9] Pinstrup-Andersen and Schioler 2000:31." Though such sophisticated analysts understand the many caveats embedded in the Malthusian narrative, there remains a wide-spread conception – echoing corporate public relations talk -- that biotechnology means more food and more food means less poverty.

[10] E.g. Centre for Environmental Studies Warangal l998; Department of Agriculture and Cooperation l998; see also Vasavi 1999; Stone 2001.

[11] For a compendium of pro-poor potentialities of the technology, see Persley and Lantin 2000; Qaim, Krattiger and von Braun, eds, 2000.

poor individuals. If opponents of transgenics are correct, but proponents win politically, the lives of the poor could deteriorate further. If proponents are correct, but critics win politically, the poor would be denied significant opportunities for improving their lives. Precautionary approaches are therefore not costless: the status quo is hardly risk-free for the world's poor. Proponents of genetic engineering argue that alternatives to some contributions of new technologies to the lives of the poor are more costly, slower, less certain, less attractive -- or impossible. Science is Promethean if honest: it cannot be assumed that all risks are known, that current practice will not be undermined by new findings, that we may be wrong, or proceeding on insufficient knowledge. For this reason, Promethean science of transgenics often loses politically to the radical uncertainty of Pandora's jug (Herring 2001).

GMOs, LMOs, Transgenics: The Political Biology of Labels

Labeling is political. It is not simply that there are multiple legal disputes around the labeling of genetically engineered products; there is more fundamentally a politics of naming the very things themselves. The Cartagena Protocol on Biosafety of the Convention on Biological Diversity covers "LMOs" or living modified organisms (Bail et al 2002). Almost universally, opponents of genetic engineering label its products "GMOs" for "genetically modified organisms." Thus develops market segmentation and a niche for "GMO-free" labeling on grocery shelves and export baskets. **"**GM-free zones" crop up in southern Brazil, but also in California. The designation "GMO" creates a special category, and thus a niche for mobilization and product differentiation, where many biologists would find none – a distinction without a difference. All existing crops are genetically modified – that is the purpose of plant breeding, which has been with us in a more or less scientific form for over a hundred years, and with us as a species for at least 6,000 years. Genetic modification is the history of agriculture. The current distribution of plant species cultivated for food and fiber has involved a radical and purposive reduction of biological diversity for instrumental human ends.[12] We would otherwise be, as a species, unable to feed ourselves.

Plant breeding alters genomes of plants -- there would be no point to it otherwise – often by means unfamiliar to a mass public imagining an idyll of Gregor Mendel puttering with his peas. In addition to familiar and now naturalized techniques of selection and crossing, there are in the conventional repertoire of modern plant breeding much more invasive and radical techniques: emasculation; intergeneric crossing [of unrelated plants of different species – e.g. *triticale,* a cross of wheat and rye by conventional breeding]; embryo rescue; haploid breeding and mutation breeding that induces potentially useful mutations, and many fatal ones, by means of toxic chemicals or radiation.[13] Recombinant DNA technology – moving a specific sequence of DNA from one place, or species, to another – expands the scope of plant breeding significantly – making it faster and more precise. This technology is appropriately called genetic engineering, the product of which is a transgenic organism. "Transgenic" is more precise

[12] On the long term, Pollan 2001; Diamond 1997.
[13] See, e.g., McHughen 2000:63-6; Winston 2002: 11-34, passim; Shelton 2004; Nuffield Council, 2004: 22-25.

as a name for organisms that result from rDNA technology; it is a biological category, rather than a political one. Which of plant breeding techniques should be considered natural, or dangerously unnatural, is one of the emotionally charged and non-negotiable vectors of a globally contentious politics. Whether genetic engineering represents one end of a continuum of plant breeding or a radical departure separates the discourse of Frankenfoods from the stance of the United States Department of Agriculture.[14] Because "GMO" is now so embedded in the policy and political landscape, authors in this volume will sometimes utilize the terminology, despite its biological ambiguity and political loading. It is recombinant DNA work that has energized the debate, because of its unique potential and consequent susceptibility: we believe the outcomes could not have happened in nature. Transgenic organisms are regarded by proponents as offering unprecedented benefits to humanity and by their critics as introducing unacceptable uncertainty, perhaps serious risk.

There are both real and strategic reasons for divergence in targets of international opposition to transgenics. As global markets have segmented, premised on variable interpretations of risk, strong interests in maintaining label-induced difference are created. In the United States, where these crops have been consumed without much attention, much less anxiety, on the part of consumers, a new market in "GMO-free" foods is emerging to join the claims of organic products. There is nothing comparable in response to genetically engineered pharmaceuticals. Nevertheless, it is true that genetic engineering creates uncertainties, perhaps risks, in agroecologies less likely to surface in a laboratory. Genes will travel through agroecological systems, with unpredictable results. Worse, traditional methods of dealing with risk seem inappropriate: there is no probability distribution from which one can characterize risks adequately. The practice of "*pharming*"-- the use of transgenic plants as factories for production of commercially useful chemicals – blurs these boundaries.[15] Some transgenic questions are thus genuinely new. Yet the intense controversies surrounding this technology resonate with fundamental developmental questions – the *telos* of societal change, Promethean promises and threats of novel technology, distribution of benefits and risks differentially across segments of society.

Because of the novelty of the technology, and its ability to create what cannot happen on its own in nature, labeling participates in limning the unnatural. Consider four poster-organisms. The tomato-with-flounder-genes had a robust life in junk-science propaganda but was a hoax (McHughen 2000 14-16). "Terminator-technology" cotton did not exist was an instrumental tactic of political mobilization that backfired in India (Herring 2005). The science of the highly politicized findings on the monarch butterfly at Cornell University is explained in context by Janice Thies and Medha Devare in this volume. Attacks on "golden rice" have denied its nutritive contributions in instrumental

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[14] The USDA position on "substantial equivalence" in end products – meaning that no differences between a transgenic and a non-transgenic identical variety can be detected – implicitly recognizes a continuum of plant breeding techniques from minimally invasive to cross-species movements of DNA.

[15] See Thies and Devare, this volume; even biologists who find gene flow in agriculture relatively manageable and unthreatening find *pharming* much more problematic.

ways, as discussed by Michael Lipton and Howarth Bouis in this volume. Yet uncertainties remain. The real science of transgenics is inevitably and openly incomplete, and thus at political disadvantage in contests with knowledge systems that know answers before the evidence is in.

Were the contributors to this volume to prevail, the stark dichotomy of genetic engineering and traditional plant breeding would not be made. All breeding involves moving genes around, and all agriculture carries risks for ecological systems. One of the banes of my teenage years was a never-ending battle against Johnson grass, an invasive and destructive pest produced by out-crossing of cultivated sorghum with wild relatives.[16] This particular Frankenweed reduces agricultural productivity and menaces biodiversity; but the source was gene flow from a conventionally bred crop.

Poverty is likewise defined in a multitude of ways, but the biological seems the most universal, the least subject to noise in measurement, definition, subjective entanglements. Robert McNamara as President of the World Bank in l974 defined "absolute poverty" as – and I paraphrase here: a condition of live so limiting as to deny the potential of the genes with which humans are born. This is an outcome notion of poverty: do people have the means of achieving the potential of the genes with which they are universally born? The absolute number of the absolute poor continues to increase globally, despite striking growth of GDP and other measures of economic activity in many parts of the world. The very existence of absolute poverty constitutes a global imperative to apply new knowledge to alleviate limits on achievement of human potential (Nuffield Council 1999; 2004). We collectively find that broad statements on the effect of rDNA technology on the poor are unlikely to be useful. Both are heterogeneous categories about which generalization obscures variance. For many in the NGO community, the very question of benefits for the poor from transgenics is part of an instrumental ideological cover for corporate globalization. The empirics thus far do not bear out the most pessimistic scenarios in regard to poverty, yet their premises warrant our collective attention if we are serious about anticipating consequences and clarifying conditions under which pro-poor outcomes are possible. Ethical choice presupposes knowledge. The public and political discourse around biotechnology has largely taken a dichotomous and generalizing form. We collectively seek to disaggregate where needed, while drawing larger pictures when possible.

An Emerging Consensus: From Terminator to Toolkit

An optimistically evoked "international community" repeatedly declares a global commitment to reduction of poverty; in some formulations, poverty reduction through application of biotechnology rises above the level of opportunity to the level of moral obligation (Nuffield Council l999). Howarth Bouis in this volume notes one moral imperative that makes precautionary or obstructionist stances problematic: "Globally,

[16] Winston 2002: 94-5 notes that Johnson grass is but one of the many "weeds" produced by plants' promiscuous breeding habits: there is considerable gene flow between wild and cultivated species.

about 3 million children of preschool age have visible eye damage owing to a vitamin A deficiency. Annually, an estimated 250 000 to 500 000 preschool children go blind from this deficiency and about two-thirds of these children die within months of going blind." In general, the human suffering and economic losses from malnutrition seem impossible of justification. Despite dramatic opposition, the general direction of movement seems clear: toward acceptance of transgenic crops by more international organizations, farmers, and the epistemic community of agricultural scientists. Endorsement of biotechnology – including positing of benefits specifically for the poor -- by the UNDP in its 2001 **Human Development Report** -- "Making Technologies Work for Human Development " -- stunned some NGOs that had counted on the organization for support of alternative development thinking.[17] The UNFAO (2004) report on the **State of Food and Agriculture 2003-04** endorsed genetic engineering specifically for the poor, joining the position of the Consultative Group on International Agricultural Research of the World Bank (CGIAR). Expansion of acreage, crops and farmers is tracked in the publications of the NGO International Service for the Acquisition of Agri-Biotech Applications (ISAAA) typically authored by Clive James.[18] This annual accounting has become the reference of record. Yet there are good reasons to think that even this upward sloping curve understates transgenic crop adoption: illegal, unregistered, gray-market "stealth seeds" cannot be counted.[19] The discovery of stealth transgenic crops in fields where they are not supposed to be – either in the biosafety sense of being approved for planting or in the property sense of violating some property claim – suggests that the movement is more substantial than even ISAAA data indicate. Farmers seem to be voting with their plows, whether or not nation-states or Monsanto confer their blessings.

Likewise, developmental professionals have increasingly agreed to something like a standard narrative of biotechnology: a shared assumption of values, institutions and empirical reality.[20] It is an optimistic but cautious consensus. Per Pinstrup Andersen and Ebbe Schioler's **Seeds of Contention** won the World Food Prize in 2001; it is in many ways indicative of the new consensus. This consensus departs both from the apocalyptic vision of the many NGOs adamantly opposed even to the testing of transgenic crops and from the transparently instrumental propaganda of multinational firms selling seeds. The metaphor of the "toolkit" is often deployed: transgenics will not solve the problem of

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[17] Supporters of sustainable agriculture and ecological regeneration objected strenuously to what was felt to be betrayal by a perceived ally: e.g. see Kothari and Chawla 2002.

[18] See his annual *Global Status of Commercialized Transgenic Crops***.** ISAAA Briefs. Ithaca, NY; specific publications from ISAAA will be cited throughout.

[19] Brazil, for example, for many years figured as zero in transgenic production; it is now among the leaders in soya. The illegal movement of glyphosate-resistant soy seeds across international and internal borders assumed such proportions and raised so many political and juridical conflicts that the myth of GMO-free could no longer be maintained. Likewise, before 2002, India would be recorded as having no transgenic crops, but farmers were growing Bt cotton in several states. See Herring, Stealth Seeds… this volume; Paarlberg 2001: Chapter 4.

[20] Andersen, 2004, building on Roe, 1991, defines "development narrative" as "a normative causal explanation, simplifying the message, and leading to a proposed action." See Dryzek 1997 for examples.

"world hunger," but represent a new tool, among others, just as many of the traditional tools are proving either inadequate to the task or come with too many cumulative externalities – particularly environmental – to be sustained (Conway 1997). To science, the narrative adds representation as a fundamental breaking point: who represents the poor. Andersen and Schioler claim to represent no one, but feel that "too many well-to-do individuals and groups from Europe and North America have taken an unacceptably paternalistic position, claiming to represent the interests of the developing countries and to know what is best for the poor within these countries." They suggest that there is an "almost silent majority" of people in low-income countries who are not being heard [p xi].

Using the right tools is not easy in this narrative; the incentive structure, direction of research and property configurations augur ill for the poor. The sharp decline in the ratio of global public-sector to private-sector research means that multinational firms dominate. Yet there is in principle no reason that public sector research could not yield results comparable to those of the private sector.[21] Research and development costs are daunting, but large nations such as China, India and Brazil have public-sector institutions that can operate at the frontier of applied research. The multinational nexus, Andersen and Schioler argue, has been important politically but has no necessary connection with modern biotechnology. Public investment in biotechnology is worthwhile, they argue, because intensification along lines of the *status quo* is unlikely to be sustainable. They conclude, after weighing logical pros and cons and looking to some evidence, that "… the organic approach, while certainly a worthwhile option in regions with the space, the labor and the consumer purchasing power … is not a cure-all (2000: 79)." Aproaches from genetic engineering seek to bypass some of the worst externalities of the "green revolution" path while avoiding the yield limitations of traditional agriculture.

These attractive scenarios in the emerging consensus are hedged by Promethean concerns: new organisms require institutional control. The final chapter of Per Pinstrup Andersen and Ebbe Schioler's prize-winning book is characteristically entitled "Moving Forward: Handle with Care." The authors recognize the problems of concentrated control of technology by unaccountable firms; they endorse ethical scrutiny of each step in evaluating transgenics; they stand for "free and informed choice" for consumers and farmers, and, emphatically: "extermination of a terminator." The terminator creates a bio-cultural abomination: a plant that cannot produce viable seeds. "Terminator technology" became the symbolic battering ram for global protests against transgenics.[22] Though the terminator has been emblematic of the hoaxes and political dramaturgy mobilized against biotechnology, the final irony is that the authors argue that gene use restriction technology is that the only certain prevention of horizontal gene flow. Opponents charged

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[21] The Chinese public-sector version of Bt cotton competes well with Monsanto's version in China, and has been popular with small farmers; it is likely to come to India *via* Nath Seeds. Likewise, public sector and public-private collaborations in India promise to provide comparable technologies.

[22] 2000: p 135. Genetic-use restriction technologies (GURT) were dubbed "terminator technology" by RAFI, a Canadian NGO, with powerful international impact.

that gene use restriction technology [GURT] would increase the cost to farmers, force them to buy more products (gene activators) and not allow them to save seed for future plantings. For reasons developed by Theis and Devare in a later chapter, terminator technologies are perhaps practicable in the field, though to date there have been no applications for field trials. More important for small farmers, there are technologies that compromise between seed saving and replicating the trait caused by the transgene, requiring reactivation only if the farmer wants the trait; otherwise, the seed reverts to pre-transgenic genome.[23] This concept averts the most serious environmental uncertainty and is compatible with concerns for seed choice and seed saving among poor farmers.

The standard narrative then has two major components that qualify what are increasingly seen as very real potentiality for pro-poor outcomes of new technology: ***Biosafety*** and ***Bioproperty***. With assumptions about adjustments to bioproperty, and establishment of biosafety institutions, the pro-biotech narrative acknowledges the main points of critics and answers their main concerns. But there is a third assumption less acknowledged or discussed: ***Biopolitics***. Recombinant DNA technology introduces a deep ideational divide on the nature of the natural. Other than true believers among market fundamentalists, development analysts find that the poor win via coalitions that use political means to overcome their structural disability in the marketplace -- minimum wages, social security, nutrition programs, medical care, transfer payments – and produce public goods important to the poor – clean water, education, law and order. Such coalitions are rare and fragile (Moore 2003); they often divide explicitly on transgenic organisms. Howarth Bouis writes confidently of biofortification as a system that has the great advantage of not needing to rely "… on behavioural change as a condition for success… [like] … as adding fluoride to drinking water in developed countries." In Ithaca, New York, the home of Cornell University, a leading center of science research and education, and inhabited by a remarkably well-educated and progressive community, there is no fluoride in the drinking water, despite widely accepted benefits for dental health, particularly for the poor. Even professional associations of dentists, for whom this public good reduces personal income, support fluoridation of water supplies. But it is politically impossible to put fluoride in the water in Ithaca, New York. Pandora has left her mark everywhere.

Critiques of biotechnology challenge the research and development as producing hasty, self-referential science in symbiotic relationships with regulators. The parallel to pharmaceuticals is too much with us to ignore. On November 18, 2004, in hearings before the Senate Finance Committee in the United States, an unpublished report by the Food and Drug Administration was cited as finding that from 1999 through 2003, an estimated 27,785 heart attacks and sudden cardiac deaths would have been avoided if patients had not used Merck's Vioxx (rofecoxib), an arthritis drug.[24] David Graham, the

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[23] Curiously, the Nuffield Council Report (2004: 51-2) does not investigate this potential, despite its concern with the consequences of pure forms of GURT. See Thies and Devare.
[24] The estimate is based on a sampling of the 92.8 million U.S. prescriptions for Vioxx between 1999 and 2003. This section relies on telecast Senate committee hearings and reportage by the Washington Post and New York Times.

associate director for science in FDA's office of drug safety, testified that the estimate is "conservative;" he said the number of heart attacks, strokes and deaths could be 139,000, with 55,000 deaths. [This number, no one in the Senate noted, exceeds considerably the deaths from use of toxic chemicals by Saddam Hussein on Kurds.] Graham explicitly argued that data was available to predict this catastrophe but was ignored by the FDA in approving Vioxx. Senate Finance Committee Chairman Charles Grassley, Republican of Iowa, rather quaintly termed the relationship between regulators and regulated too "cozy." Dr. David Graham claimed that Vioxx "may be the single greatest drug-safety catastrophe in the history of … the world."

Critics of biotechnology doubt the neutrality of science; they argue that safety largely depends on findings by the regulated firms themselves (Winston 2002: 58-82). Suppression of troubling data is a standard finding in science studies. Moreover, critics charge, most of the currently available technology was developed for crops and conditions of wealthier farmers and countries as opposed to crops widely grown by poor farmers in poor countries. There is no assurance that research driven by the profit needs of corporations or of wealthy farmers will coincide with the needs of the poor. The implication in the standard narrative is that redirection of research and development is necessary for reaching the poor. The political economy of this outcome, even if overstated, is valid: unlike the international research and distribution regime of the "green revolution," most of the research in genetic engineering is in the hands of for-profit firms, rather than international public sector and national research institutions. There is little private incentive to produce for small markets of poor people, especially when the political climate for acceptability of transgenic crops in low-income countries is so uncertain or hostile (Potrykus 2004). Orphan crops could thus well join orphan drugs as instances of market failure. Addressing market failures that produce human misery is surely something development policy at its best accomplishes.

Getting the institutions right – public, private, national, global – for biotechnology is a necessary condition for purposive pursuit of poverty reducing outcomes (Cohen, Komen and Zepeda 2003). Where both Promethean and Pandoran political discourses misdirect attention is in failing to disaggregate both biotechnology and poverty: across nation states, social stratification systems, crops and agrarian structures.

Disaggregating Pro-Poor Claims

Though much of the debate on poverty has been about farmers, most of the world's poor do not control food-producing land; their relation to the genomics revolution is through food prices, biofortification of staples for nutritional deficiencies, bioremediation of environmental hazards, and a number of promises still on the drawing board – where they may well stay if the political debate remains unsettled. Though the poor are obviously a heterogeneous category, some primary desiderata are universal:

A. *Incomes*: For farmers, the question is net returns from new seeds, which depends on an interactive effect of yields and costs. Net employment and wage effects (shadowing productivity gains) relative to food prices are most important for the most vulnerable poor, the field workers who have only labor to sell.

B. *Nutrition*: The poor need more affordable and more nutritious food to improve their health and to live longer and more productive lives. Low-cost food is obviously important; yet the poor consumer's gain can be the poor farmer's loss unless total factor productivity on farm rises.

C. *Environmental integrity*. More often than for the rich, livelihoods of the poor depend on ecological integrity; moreover environmental degradation affects most quickly and seriously those with the least flexibility in life choices.

This simple accounting does not exhaust the needs of the poor – one thinks of land, shelter, medical services, political access, cultural acceptance, and personal security among others. Nor should consideration of transgenics obscure the major levers through which poverty might be alleviated – the international regime of subsidies and protectionism in rich countries, for example, has a much larger impact on incomes of the rural poor than any transgenic crop. Yet technology may matter fundamentally.

Income: Analytically simplest, at first blush, is the question for farmers who own their own land: under what conditions does genetic engineering allow scale-neutral deployment with substantial income benefits for small and marginal farmers? Scale-neutral technical change can in theory lower the size threshold of a viable farm, alleviating to some extent the hazard of being too small to be viable; such change responds to the declining size of holdings world-wide. The smallest and most marginal farmers are those most at risk from biotic and abiotic stresses on crops, as they are driven to the most difficult land with the fewest resources for amelioration; water may be the most critical example.[25] Most evidence from the field is for a limited variety of crops developed for use in relatively high-income countries: glyphosate[herbicide]-resistant soybeans, corn (maize), canola; corn resistant to the corn-borer and cotton resistant to the bollworm. Even so, there is evidence for the scale-neutral interpretation with superior net-returns discussed in various chapters of this volume. Pray and Naseem discuss comparative national experiences with widely cultivated transgenic crops. The clearest evidence is probably from Bt cotton, where small farmers have increased net income through two mechanisms: less cash expenditure on insecticides and better protection from bollworm pests, hence better yields.[26] David Zilberman and his co-authors explain theoretically why this outcome is predictable. The evidence that small farmers can take advantage of biotechnology to avoid debts for inputs, provide some insurance against crop failure and raise production has led to endorsements by development organizations such as UNDP (2001) and the UNFAO (2004).

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[25]There are possibilities in reducing salinity and moisture stress through rDNA technology; see Nuffield Council 2004: 3.42; Lipton this issue.

[26] On the international pattern James, 2002. On India, see Bambawale et al, 2004; Rao 2004a, b, c; on South Africa, Ismael, Bennett and Morse 2002. In this volume, the evidence is discussed in contributions by Herring; Roy et al.; Lipton; Pray and Naseem.

The exception must be when the cost-of-entry barrier is too high for poor farmers in imperfect credit markets, as could be the case with expensive seeds from profit-maximizing monopolists. This concern for distribution of bioproperty is warranted, if exaggerated. There have been successes in humanitarian use concessions of intellectual property, and a segmentation of markets to permit poor producers to avoid fees charged to commercial producers (Kryder, Kowalski, Krattiger 2000). As the contribution of Lee et al. to this volume illustrates, adoption of transgenic papaya did not follow the three stage S-curve familiar in technology adoption, wherein larger farmers appropriate innovators' rents because they can stand more risk and command more resources. Rather, both in numbers and acreage the papaya engineered to stop the ring-spot virus that was devastating crops in all growing countries was adopted very quickly, and more by small farmers than by large. Part of the reason might be termed the *insulin effect*: the authors note that rapid adoption was driven by "the severity of the disease which the transgenic variety was developed to surmount; the high likelihood of experiencing devastating crop failure if a grower did not adopt" – ie, there was no alternative. Unlike lumpy capital investments such as tractors or tube-wells, transgenic seeds -- both in theory and on the ground -- exhibit a great deal of what Rogers (1995) refers to as "trialability" -- defined as the degree to which experimentation with an innovation may be done on a limited basis. Moreover, as Florence Wambugu (2000) stresses, the technology package is in the seed itself, allowing known practices to be applied without complex and stratifying extension infrastructure and knowledge hierarchies. What eventually hurt small farmers who adopted transgenic papayas was not a failure of the technology, nor intellectual property, but regulatory resistance from the major market, Japan – which is seemingly legal under WTO rules, but contested.[27]In a deeply ironic outcome, the beneficiary of Japan's restrictive position on transgenics was Dole, one of the multinationals critics expect to win from biotechnology, not from its proscription.

Evidence to date does not indicate widespread resistance of small farmers to biotechnology where it is available and affordable; quite the contrary, an underground market in unofficial seeds has sprung up in many countries. Gray-market seeds spreading underground, farmer to farmer, in Brazil and India, for example, eluded both state managers of biosafety and corporate enforcers of property rights, as explored in the chapter on "Stealth Seeds." Unless we assume small farmers to be irrational, this evidence suggests income-positive effects. The worst-case scenario would be for improved yields from transgenic crops driving down farm-gate prices for poor farmers who lack access to the technology but suffer from the backwash price effects. Michael Lipton's contribution discusses how this outcome was one of the failures of the "green revolution" in poverty outcomes. The outcome for poor producers for the market could be negative even as the outcome for net-food purchasers among the poor would be positive. Should commercially driven export economies continue to adopt cost-saving

[27] World Trade Organization regulations permit such technical barriers to trade when "information about health, hedonistic, or ethical attributes of agricultural products is either unknown or asymmetrically distributed between producers and consumers, and the transaction costs of obtaining this information are prohibitively high for consumers." Roberts *et al*., 1999.

biotechnology, farmers in resisting nations will face new competitive disadvantages piled on top of the subsidy and protectionist market-rigging of wealthier states.

Income effects for farmers then depend on the regime of property rights and mix of public/private investment in new technologies. A large difference between the “green revolution” and the “gene revolution” is the dominance of public expenditures in the former, private capital in the latter, with implications carefully explored by Michael Lipton in this volume. Even so, it seems that the burden of patents, private-property claims and technology fees have been exaggerated by opponents of transgenics. Activists in India said that Monsanto would crush the peasants with monopoly power, for example, but in the event many farmers preferred the stealth seeds of the gray market to the official and expensive Monsanto seeds – though both produce profits for farmers. Stealth transgenic soy seeds likewise have spread throughout Brazil for at least seven years free of royalty payments of any kind. The strong property claims of political rhetoric and TRIPS negotiations seem hard to enforce on the ground, whether in Southern Brazil or Western India. It is certainly true that Monsanto has been quite vigorous and somewhat successful in demanding enforcement of its property claims in North America, and comes down very hard on relatively small farmers to set examples (Liptak 2003:18), but it is equally clear that such strong manifestations of intellectual property are by no means automatic on a global scale.

The most obdurate problem of rural poverty is that of the landless workers who must seek wage employment on whatever crops need labor. They are put at risk by crop choice, but seldom have voice. Michael Lipton notes that the ratio of poor farm workers to poor farmers has been “steadily increasing.” What is a livelihood for the laborer is a cost for the farmer. In high-wage agriculture, labor-saving technologies have attractions in the market and will draw investment and development. Herbicide-resistant crops, for example, save farmers money and labor under certain agronomic conditions;[28] if they are poor farmers, adoption could improve their position by freeing up labor time for other crops or other jobs. But reducing aggregate demand for labor under those agrarian conditions either destroys livelihoods or puts downward pressure on wage rates or both – in either event deepening poverty if no other systemic parameters change simultaneously. More important, the rural poor who depend on weeding labor for a livelihood are frequently those cumulatively disadvantaged along other dimensions of social stratification: women, depressed castes, ethnic minorities. In those circumstances, even if herbicide-resistant crops would be desirable on other grounds – for soil conservation, for example – a pro-poor approach would necessarily begin with simultaneous discussion of land reforms, rural public works, food subsidies, and other mechanisms to avoid making the poor pay for technology-induced profits (e.g. Herring 2003). It is ethically and empirically wrong to load everything on the seed.

If transgenic crops reduce demand for labor, agrarian structure would differentiate poverty effects. Where holdings are small and equally divided, as in China, smallholders

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[28] Of 67.7 million hectares planted to GM crops in 2003, 73 per cent were selected for herbicide tolerance (ISAAA data); On Argentina, see Nuffield Council 2004: p 40-42.

would be saving their own labor, not depriving others of employment; this seems to be the case with Bt cotton. Where holdings are larger and less equal, as in India, laborers would face less work applying pesticides.[29] On yet another hand, work opportunities lost in chemical applications may be compensated by more harvest labor if yields increase, and by safer ground water and less exposure to toxins. This scenario could present a difficult trade-off for the very poor, but may not be inevitable. For example, in Bt cotton in India, if wages are based on weight harvested – rather than a daily wage – income would increase with yield and with density of viable bolls of cotton, as seems to occur on the ground.[30] Moreover, whatever the effect on demand for spraying labor, protection from crop loss has implications for the poor: there is no income for the landless at all in harvesting crops destroyed by bollworms. It was only fields of Bt cotton that survived the "bollworm rampage of 2001" in Gujarat (Joshi 2001, Jayaraman 2001). To the extent that transgenics reduce risk of crop failure, they provide a macro-insurance policy for the landless poor, as they do for farmers.[31]

There is yet one more level of necessary disaggregation. Michael Lipton concludes in this volume that pro-poor biotechnology must "prioritise sustainable intensification of appropriate currently cropped land via yield-enhancing and yield-stabilising traits, not labour-saving traits such as glyphosate resistance (except in situations, rare in developing countries, where such traits on balance cut poverty)." Where farm labor is either scarce, or mostly supplied by farmers who own their own land, ability to control weeds may enhance yields, returns to labor, and opportunities to take on more land for cultivation when available. These outcomes could be pro-poor, depending on the net effect on costs and returns. This view of labor constraints for African farmers has been long stressed by Florence Wambugu (2000). The objective interests of the rural poor in India and Africa may well diverge in the concrete matter of herbicide-resistant technology. However, even in India, demand for rural labor is highly uneven temporally: an aggregate surplus of labor, indicated by insecurity and poverty among landless workers, does not mean that there are not labor shortages in times of peak demand. Farmers will frequently tell investigators that labor is in short supply – often meaning that they cannot hire in discrete bundles of time separated by enforced idleness at a wage that gives them a decent profit but leaves the laborer below a pitiful poverty line over the course of a year (Herring and Edwards l983). These disaggregations of agrarian structure and crop traits are illustrative and could be multiplied.

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[29] Comparative data from James 2002; Ruifa Hu and Carl Pray, pers communication, find in their survey of about 400 Bt farmers in China, self labor constituted 96.5% of the total labor used, only 1.7% was hired labor.

[30] See discussion of ACNielsen study of Bt cotton in India, which finds a large positive wage effect, as well as interview evidence discussed in Roy et al, this volume.

[31] It is clear that the storm-generating claims on yield effects of the Qaim and Zilberman (2003) piece in **Science** were based on an unusually devastating bollworm infestation and represent not a typical outcome but a limiting case, as the authors recognized. On cotton in actual growing conditions in India, see discussion in Roy et al, this volume. Bt cotton in India has been in the field too short a time, and with too few independent and credible studies, for there to be firm conclusions on this point.

New segmentation of markets for agriculture is a phenomenon entirely driven by the Promethean/Pandoran discourse. If the United States Department of Agriculture is correct in its stance on "substantial equivalence," much of the market segmentation is profoundly artificial. Nevertheless, there are real implications of ideational divides. Here European consumers have shaped the world. Though there is clear softening of official European hostility to transgenics, it is not yet clear how identification and labeling of transgenic products in the global market will affect opportunities for poor farmers. Labels such as "organic" provide market niches for labor-intensive farmers to sell at a premium in rich countries. But "organic" legal usage in the United States precludes transgenic seeds, whatever the cultural practices. The example of transgenic papayas in Japan underscores the vulnerability of small farmers to discrimination against transgenic crops, as David Lee and his co-authors explain in this volume. "[I]n the interests of addressing alleged food safety problems … Japanese import restrictions effectively penalize small and medium-sized Hawaiian papaya producers, and in turn, directly foster increased market share and potential market dominance by a major transnational company with global reach." Ironically, the winner in the banning of transgenic papaya by Japan was the multinational Dole.

Health and Nutrition

Most of the global poor are not farmers at all. The overwhelming facts of poverty are insecurity and restricted options: food comes first, and consumes a larger share of expenditures the poorer one is. Moreover, food expenditures of the poor tend to be weighted towards staples rather than fruits, vegetables and animal protein. As deadly as protein-calorie malnutrition is, it is increasingly recognized that micro-nutrient deficiencies generated by excessive reliance on staples in an unvaried diet may be equally or more debilitating. The often imperceptible "hidden hunger" of micronutrient deficiency reduces energy, stunts growth, impairs cognitive development, and raises morbidity and mortality rates. The potential of bio-fortification of staple food crops – of which pro-vitamin A Golden Rice is the poster plant -- figures heavily in claims for the life-saving potential of biotechnology. The model is clear: engineering staple plants to make bioavailable nutrients for those who cannot afford the varied diets recommended by nutritionists seems superior both in terms of cost and sustainability to alternatives such as supplementation or fortification of processed foods. Howarth Bouis notes in this volume that the situation in the South reverses that in the North, where consumers benefit little if at all from transgenics, but have been the guinea pigs for testing out allergenicity and other putative health risks. Malnutrition and ill health in poor countries are more common. Additionally, the poor lack adequate access to health care, typically spend 70 percent of their incomes on food, and have diets heavily weighted toward staple foods, which "lack the vitamins, minerals, and very likely other food components necessary to sustain good health and minimise the risk of adult onset diet-related chronic diseases."

Biofortification may well prove to be the contribution of biotechnology most significant for the poor; cash can be lost, crops can be destroyed by natural catastrophe, recessions can dry up wage-labor opportunities, international market rigging can reverse gains from higher productivity, but so long as adequate entitlements to food staples can be maintained for the poor, nutritional enhancement of those staples contributes directly and significantly to welfare. Spatial disaggregation is important as well. As Howarth Bouis argues, "Biofortification has the potential to provide coverage for remote rural populations, which supplementation and fortification programs may not reach, and it inherently targets the poor who consume high levels of staple foods and little else." There is much that is unknown. How practical are nutritional enhancements in different agronomic regions and crops? Will consumers accept transgenic foods? Will farmers grow bio-fortified crops? Are there are dangers in over-dosage of specific micro-nutrients for specific individuals?

Bouis illustrates the possibilities in biofortification by discussing three breeding sub-strategies that may be sought separately on in combinations: "(i) reducing the level of antinutrients [e.g. phytic acid] in food staples, which inhibit the bioavailability of minerals and vitamins, (ii) increasing the levels of nutrients and compounds that promote the bioavailability of minerals and vitamins, and (iii) increasing the mineral and vitamin content." The effort to improve the micronutrient content and/or bioavailability of commonly eaten foods does not obviate attention to continuing efforts to provide the means for "a substantial improvement in dietary quality by higher consumption of pulses, fruits, vegetables, fish, and animal products, which the poor need and already desire, but cannot presently afford." Direction of research in this manner presupposes motives other than profit-maximization; Bouis himself is engaged in a major global effort to utilize non-commercial monies on a large scale to solve biological problems that would otherwise remain market failures.

Claims that transgenic crops are themselves a threat to health are persistent but without evidence. In its **State of Food and Agriculture 2003-2004**, the UNFAO evaluated a large body of scientific literature on transgenic crops and found no evidence of any danger to human health from food plants currently being grown. However, they note that multiple-gene events under development warrant further study. The Nuffield Council report (2004: 4.47) concludes from a survey of existing literature and that "there is no empirical or theoretical evidence that GM crops pose greater hazards to health than plants resulting from conventional plant breeding." They go further to suggest that biotechnology may have potential for reducing known dangers in conventional foods from substances such as glucosinolates, alkaloids and mycotoxins. We can now be fairly certain that no one will die of Bt maize, but Meade et al (2004) in an analysis published by the US Centers for Disease Control find that " foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year." Regulatory attention on vague and hypothetical risks[32] of new crops has opportunity costs for attention to threats from conventional foods.

Environmental Integrity: The poor are the first victims of environmental degradation. They depend more on the environment for livelihoods and have fewer exit options than the rich. They are also the first victims of dangerous agricultural technologies. Critics of

[32] My anti-GMO colleagues in Palakkad district tell me I should not feed these foods to children, as what may not be apparent in 10 years may be apparent in 30 or 40 years. This is an infinite regress.

biotechnology have conjured truly terrible ecological disasters; Vandana Shiva and colleagues (1999) wrote that the "terminator" would "terminate biodiversity" if India allowed test trials of Bt cotton. Predictions of gene flow and superweeds conflate to biological Armegeddon (Winston 2002: 235 ff; McHughen 2000: 261-2). No serious scientist doubts that there are uncertainties: Klaus Ammann says "those who have no anxiety, they are the fools." But our species does have reason. Modern agriculture poses known risks for humans and biodiversity; the struggle against pests and weeds has reached desperation and treadmill levels in many settings. There are dichotomous positions on the environmental consequences of transgenics. Janice Thies and Medha Devare carefully explore uncertainties on the nature and magnitude of possible ecological costs, based on existing evidence. The question for any technological change is always: compared to what?

Synthetic chemicals in agriculture are among the most toxic substances in circulation; the poor are especially vulnerable, as they cannot afford to be too picky about what jobs they take. If someone is going to put on a backpack sprayer and walk un-protected and often half naked through fields spewing toxins, it is likely he will be poor. If anyone is going to drink contaminated surface water, or water from shallow wells, she is most likely to be found at the bottom of the social hierarchy, not the top. Here the claim of Bt technology, especially in cotton – a crops especially prone to pests and toxins -- is compelling. There is evidence from China on improved farmer health in Bt-protected fields as opposed to sprayed fields.[33] Reduction of pesticide spraying can then be expected to help curb the epidemic of pesticide poisoning (Jeyaratnam 1990), conserve some water, and reduce the wholesale destruction of both beneficial insects in the fields and wildlife that depends on those agro-ecological niches. Use of insect-resistant crops also reduces insect damage, improving yield but also measurably lowering contamination of food crops by mycotoxins produced by opportunistic fungi that infect wounds made by grazing insects (Munkvold *et al.,* 1999).

Against the hypothetical Armageddon narrative, proponents of transgenic crops have an environmental story to tell as well (e.g. Horsch and Robert T. Fraley 1998). Per Pinstrup-Andersen and Ebbe Shioler note that increases in aggregate agricultural production have historically come from two sources other than improved seeds – conversions of landscapes and application of chemicals to fields. Both have serious ecological consequences. Conversions fragment and destroy habitats and disrupt eco-system services. They argue that "… without the scientific breakthroughs associated with the Green Revolution, the increase in India's wheat production alone between 1966 and 1993 would have necessitated plowing another 40 million hectares of land (p 20)." Of course the "green" revolution was not greenat all in an environmental sense, but rather involved significant deterioration in natural systems (Conway l997). Water, the lifeblood of nature, was diverted, poisoned, wasted. Nevertheless, raising production requires either more per acre or more acres, and the source of more acres is typically ecological destruction. Widespread cultivation of transgenic plants in North and South America has produced no evidence of environmental disasters in the making. On the other hand, the

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[33] Huang et al, 2002; Pray et al, 2002; James 2002: 138-147 et passim.

roughly four million small cotton farmers in China who switched to Bt cotton used less pesticide on crops with higher yields. Surveys of 400 farmers in northern China showed the adoption of Bt cotton has led to dramatic reductions in the use of dangerous organophosphate pesticides and an FAO class II pyrethroid. This reduction in pesticides reduced the incidence of pesticide poisonings significantly (Pray et al 2002).

Concern for biodiversity is common in critiques of transgenics. For plant biodiversity, it is a curious concern: conventional plant breeding replaces land races with elite line monocultures. As Thies and Devare conclude: "such a result is no more, nor less, a concern with transgenic crops." Zilberman and his colleagues find that there are reasons to expect that crop genetic diversity will not decline with adoption of transgenics; they cite the evidence of Klaus Ammann, who "finds that genetic uniformity of crop varieties has decreased by 28% during the period of introduction of transgenic varieties in the United States. The evidence suggests that introduction of GMVs around the millennium did not have significant effect on genetic uniformity." With regard to fauna, the selectivity possible in transgenic endotoxins should improve biodiversity in comparison with wholesale spraying of generic toxins. In China there is evidence from agricultural extension agencies (Pray et al 2001) and scientists (Wu 2002) that Bt cotton has greatly increased the number of insect species found in Bt cotton fields. Both observations make sense. Generic toxins kill indiscrimately; non-target fauna – and their predators – suffer high casualty rates. Bt crops target only a narrow range of *Lepidoptera*: the insect must attack the plant to receive a dose of toxin. The purpose of agriculture is to *reduce* diversity in the fields, removing all competition from the crops the farmer wants to thrive; transgenic breeding offers advantages of more precise genetic modification than conventional techniques. One might well expect the net effect of transgenics to be greater crop diversity because of faster breeding, more precise breeding to suit particular conditions, and the illicit on-farm breeding program associated with stealth seeds. Monsanto has three officially approved Bt cotton varieties in India; the underground market with the same transgene has at least a dozen, perhaps double that.

Disaggregation produces complex analytics that require significantly more empirical research than exists; in this sense, the serious literature on transgenic crops and poverty is in its infancy. Thies and Devare, in analyzing one of the poster animals in the gene wars – the monarch butterfly [*Danaus plexippus* L.] as affected by Bt toxins -- remind us that there will be variance across transgenic crops modified by different genetic events [particular gene insertions]; and that effects on non-target organisms can be understood only by disaggregating time: if plants flower at different times, the possibilities for gene flow are reduced in comparison with simultaneous flowering periods. The possibilities for ecological effects then need attention to varietal differences. It was on this grounds that one cultivar of Bt maize (event 176) was not re-registered with the U.S. Environmental Protection Agency in 2001. The variety contains a pollen-specific promoter and consequently exhibits significantly higher pollen toxin levels than Bt11 or MON810 Bt corn. Only what Thies and Devare call "the dialectics of normal science" will sort out these effects, crop by crop, event by event.

Pitting certain benefits against uncertain dangers presents a difficult public-choice dilemma. When probability distributions are known, risks can be assessed rationally –

e.g. whether to fly or drive to Chicago. It is still the case with transgenics and environmental change that we have uncertainties, not probability distributions of risks. It is not helpful to say, as techno-optimists sometimes do, that science should decide; there is no scientific means of placing values on uncertain outcomes. The global movement against corporate globalization is virtually unanimous in rejection of transgenics. Risk aversions are not subject to refutation; some people fear airplanes, others fear statistically uncommon crimes, others fear rare diseases – no data will determine which preferences are right. The only solution to this public choice problem is some interaction between democratic processes and biosafety institutions. The poor are the least likely to be heard in these forums under existing institutional arrangements.[34]

BioInstitutions: Property, Regulation, Safety

Property figures prominently in any poverty discussion; transgenics are no exception. Property enables the capture of income streams from innovation. If private firms are to invest in biotechnology, they expect market returns, presupposing strong and enforceable property rights. It is no accident that the concept patent on the terminator was for a "Technology Protection System."[35] But there is not much money for technology fees on subsistence farms. Moreover, since the terminator remains under wraps, inability to control the technology and inability to enforce property rights on the ground limit private interest in biotechnology for the poor. Regulatory delays tie up capital and introduce uncertainty. Pray and Naseem note in their chapter that "multinational firms are unwilling to make the necessary investments in biotechnology research relevant to developing country agriculture due to limited market potential, fear of piracy of their intellectual property and the high cost of meeting regulatory requirements." The answer in the standard narrative is more investment by public sector institutions, where public interest -- not private return -- governs allocations. But with support for agriculture declining in aid budgets, and international institutions' budgets already stretched, would taking on a transgenic initiative divert funds from proven uses or higher priorities? If

[34] For results from a major project testing the conceptual and empirical dimensions of this issue, see "Democratizing Biotechnology: Genetically Modified Crops in Developing Countries," Institute for Development Studies, University of Sussex, Brighton, UK www.ids.ac.uk/biotech.

[35] The patent is held by Delta and Pine Land Company, in collaboration with the United States Department of Agriculture's Agricultural Research Service -- U.S. Patent 5,723,765 entitled "Control of Plant Gene Expression," granted March 3, 1998 on a concept referred to as the Technology Protection System (TPS). Monsanto's attempt to purchase Delta and Pine Land failed, though this fact did not change the global protest focus on "Monsanto's terminator." Despite its prominence in discourse, terminator technology was not commercialized, due in large part to vigorous international protests and intervention of the President of the Rockefeller Foundation, Gordon Conway [personal communication].

transgenic technologies represent just a "tool in the toolkit," how much can be spent on this tool when there are so many other tools missing, dulled, inappropriate?

Pro-poor opponents of biotechnology argue that monopoly power will soak the poor for super-profits (Shiva et al 2000). About 90 percent of research expenditures on biotechnology occur in industrialized countries, mostly in the private sector. But the data do not support a super-profit gold-mine interpretation of corporate behavior: Pray and Naseem show that private firms are decreasing their investments in agricultural biotechnology even as public sector institutions in poor countries are increasing investment. Even conceptually, it is not clear that private investment precludes collective benefits from technology. Advocacy groups around the poor world have used cassette tapes and video cameras, as well as the internet and pirated software, to aid their efforts at mobilization and expose global injustice and crime. Michael Lipton argues that critics have a point in the claim that the poor are unlikely to be served by the "focus, so far, of GM on 'cottonseed and chicken-feed' (soy, yellow maize) …" But does the basic science involved not have implications far beyond those seemingly humdrum applications?

The first field trials of transgenics were approved in l987; more than 11,000 field trials of 81 GM crops have been approved globally. The single most tested crop is maize (corn), followed by canola, potato and soybeans (Pray and Naseem, Figure 3). Soybean trials rank fourth, tied with cotton at 7 percent each in approved field trials worldwide. Though it is true that applied research on subsistence crops has been relatively neglected, Pray and Naseem note that field trials in both wheat and rice have increased in recent years. Yam has not been certified for field trials, but other "orphan commodities" -- e.g. bananas, sweet potato, lentils -- have received approval for field trials in at least one country each. There are on the table, and in a few cases in practice, innovative and practicable alternative forms of pro-poor bioproperty. Philanthropy joins public-sector efforts: in 2003 the Gates Foundation granted $25 million for the CGIAR 'challenge grant' on staples bio-fortification (see Bouis, this volume). As the transgenic cropping revolution unfolds, property rights have proved much more fluid, contingent and variable than pro-poor opponents of the technology had feared. China's public-sector Bt cotton seems to be quite successful, competing with Monsanto's version locally and traveling to India *via* a partnership with Nath Seeds. In India itself, public-sector research is picking up, though still far behind that of China. Intellectual property claims also turn out to be quite negotiable. Extremely complex property claims in Golden Rice have been sorted out to privilege poor producers while allowing for fees on rich farmers.[36] This kind of market segmentation may serve as a model for future humanitarian transfers of technology (Lybbert 2003). The analogy to pharmaceuticals seems clear: market-driven

[36] Golden Rice required 70 patented technologies controlled by 30 institutions (Kryder, Kowalaski and Krattiger, 2000), which to pessimists constituted an impossible hurdle, but a solution was found.

distribution with strong property rights is inappropriate for serving the needs of the poor, but market segmentation amid global diffusion of technology is not impossible.[37]

The standard narrative recommends redirection of research and public participation in property, but Michael Lipton asks the truly profound question: is it not possible that the science itself will enable pro-poor outcomes, whatever the incentives directing research? "The 'supply side of science', from Crick and Watson right through to plant breeders, is *not* just a response to farm-level factor prices. True, it responds to peer pressures and career incentives, and (especially at the sharpest end of applied science) these are partly created by firms that *do* respond to factor prices, but that is not the whole story." It seems that Bt cotton, for example, helps free farmers from pesticide merchants and debt, whatever the original intent of Monsanto. There are existing agreements for "humanitarian uses" of proprietary technology; public-private partnerships; public-sector transgenics, and farmer-created creolized transgenics that respect neither state nor WTO. Will Monsanto be any more successful than Microsoft or Sony in preventing appropriation of intellectual property? The ground reality is that property rights are not self-enforcing.[38] It would seem that the transgenic genie is out of the bottle.[39]

Who benefits from the global spread of transgenic crops? Pray and Naseem conclude from their analysis that "farmers and consumers are the primary beneficiaries of GM crops so far [in developing countries]. This is the case even in countries that have very strong intellectual property rights, reinforced by technical and other institutions to prevent unauthorized copying." Is it possible that "farmers" in general could benefit but poor farmers lose in the shift from public to private-sector dominance of seed property? To the extent that transgenics require more upfront cash for technology fees than alternative seeds, they will reinforce the advantages of better-off farmers. The poor are excluded from or disadvantaged by credit institutions and by definition are less able to

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[37] When the Indian firm Cipla entered the African market, multinationals with prohibitively priced AIDS drugs had either to write off the market or adapt with competitive pricing. The possibility remains that just as there are "orphan drugs" -- abandoned for lack of market because only poor people get the disease --there may continue to be orphan crops, as the poor lack both economic and political power.

[38] Monsanto essentially admits that its very punitive tactics in very strong property regimes such as the United States – suing farmers to bankruptcy – are a means of enforcing otherwise unenforceable claims. Since it is impossible to catch all the farmers who break contracts prohibiting replanting transgenic seeds, they seek to make an example of a few farmers in highly publicized cases (Liptak 2003:18).

[39] Naseem and Pray note that descriptions of many proprietary technologies in laboratory use have been published. Moreover, "[S]ome genes are in commercial use and can be obtained through reverse engineering, and some techniques have made their way to developing countries via unauthorized routes." Patents either cannot or have not been obtained in many – perhaps most -- low-income countries, and are unenforceable in others.

afford cash payments from savings. They often pay more for credit. Precisely the same probabilities of lower ranking in the social hierarchy that make poor farm laborers especially vulnerable to income insecurity and nutritional crisis afflict small farmers in stratified agrarian systems (Herring l977). More creative credit institutions are in general of special importance to the poor, especially under conditions of technical change.[40] The worst-case scenario for poor farmers would be one in which technology fees were prohibitively expensive – and enforced – and yields were dramatically improved on the farms of early adopters. In this case, "farmers" as a class could still benefit, but poor farmers would be caught in a backwash of lower output prices because of increased yields on adopter-farms, but with no reduction in input costs or increased yields on their own farms. Technical change in this scenario would accelerate agglomeration of ownership and the ruin of small farmers – the dangerous scenario of Malthusian excess in raising production. Costs of managing "surplus" production afflict nations such as India that Malthusians target as needful of new technology.

The final institutional caveat in emerging conventional wisdom is an effective regulatory regime for biosafety following the Cartegena Protocol. Discussion of these institutions often conveys a certain magic-wand quality. The most difficult questions are without answers: How much regulation? Will regulation work? Are the results worth the costs? What metric would determine how much to spend? Thies and Devare note that in the United States 100 times more is spent in technology development than in risk assessment and monitoring. Is this too high or low a ratio, or, in the Goldilocks formulation, "just right"? They note that transgenic crops have an "enviable and unblemished record" as regards environmental safety. Yet, it would seem that the development of multi-gene insertions and unregulated farmer experimentation will almost certainly challenge that record over time. There is already a great deal of gene flow among plants; more critically, whole genomes are continually inserted into agricultural and other ecologies via invasive plants (Pimentel et al, 1998) – almost certainly a greater danger than the flow of a single gene, which to be of concern would have to increase the fitness of the wild relative significantly. The Center for Biological Informatics of the U.S. Geological Survey estimates the costs of invasive species at $138 billion per year in the U.S. (http://invasivespecies.nbii.gov/). Where should the biosafety regulatory dollar be spent? Costs of regulatory regimes for transgenics are high and there are many competing priorities; the poorer the country the more poignant the trade-off. It would be unfortunate for India to tie up hundreds of microbiologists doing unnecessary paperwork when biofortification research goes begging, or to track cotton pollen at the expense of invasive species. It is hard to argue that scarce public monies should be expended to make the world safe for Monsanto.

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[40] For these same reasons, to the extent that transgenes substitute for upfront cash costs, they are of special benefit to the poorest farmers. For example, debts at usurious rates to pesticide firms were a significant source of cotton-farmer financial crisis and widely publicized farmer suicides of l998 in India (Centre for Environmental Studies Warangal, l998; Department of Agriculture and Cooperation, l998). It is now clear that the Cry1Ac endotoxin in cotton in India in practice substitutes for pesticides in a very cost effective way, more so when technology fees are avoided than when they are paid.

Biosafety regimes will certainly consume resources; will they work? Seeds are not only divisible as working capital – contributing the scale-neutral characteristic of at least some transgenic crops, and hence their contribution to poor-farmer income -- but sufficiently divisible to evade the Panopticon bodies assumed in official biosafety discourse. The original import of Bt cotton seeds into India was one-hundred grams; there could now be several million acres under unauthorized transgenic cotton in the field – no one knows. *Refugia* set-asides are recommended in order to prevent development of resistance to endotoxin-producing transgenes such as Bt; it is clear that small farmers would be disadvantaged by these requirements – *and* that many, perhaps most, small farmers are ignoring them. Worse, the science is utterly unclear: if there are alternative hosts for the insects, as seems to be the case for bollworms in India, any *refugia* requirement is an unnecessary cost imposed on farmers and regulators alike.[41] As David Lee and his collaborators demonstrate in this volume, identity-preservation measures for segregating and labeling transgenic crops are neither costless nor foolproof. In 1999, Aventis Corporation's StarLink corn hybrid, containing the Cry9C *Bt* toxin gene for resistance to European corn borer, was discovered in corn products within and exports from the United States. No ill effects from Starlink have been demonstrated, but the variety was approved only for non-human food uses. Nevertheless, food processors and distributors throughout the marketing chain were required to remove all products containing StarLink DNA, at a total estimated cost of $1 billion (Moose 2003). This entire operation may well have been a complete waste of food and money.

Discursive reifications of both seed and state – or "patents" and "biosafety regime" -- seem oddly orthogonal to ground experience so far. Opponents of biotechnology fear monopolization of property; proponents assure societies that biosafety regimes can control nature. Both constructions are proving problematic. Intellectual property in action is what farmers can make it mean; property is a relation, not a quality of a commodity. Seeds are highly portable; the very idea of borders becomes as problematic in the genomics revolution as it has proved to be for digital files, drugs, arms, information. Saved transgenic seeds and farm-to-farm exchanged seeds undermine both bioproperty and biosafety regimes – a useful corrective to the presumption of monopoly power of multinational corporations, but troubling for the optimistic discourse on biosafety. In both Brazil and India, farmers not only cross transgenes from Monsanto technology to fine-tune local varieties, but save seeds to cut costs. Unauthorized creolized Bt cotton seeds spread underground in India, undetected by the nodal authority for enforcement of Cartegena Protocol provisions in Delhi – the Genetic Engineering Approval Committee in Delhi (Jayaraman 2001). Once it discovered the seeds via commercial rivalry – not its own devices -- the GEAC proved essentially impotent. As a

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[41] See Herring's chapter below. There was "lively debate" on this question at a recent meeting of a scientific board of the US Environmental Protection Agency on this topic, with no resolution; the "louder voices" supported more research to improve data bases – not surprisingly. Pers. com. from Janice Thies, who attended.

result, a kind of genetic anarchy evolved in India's cotton regions: farmer-generated Bt crosses, F2 seeds of earlier crosses, unauthorized transgenic varieties produced by small companies and individual farmers, and the three officially approved Monsanto Bollgard varieties, all competing for space in the fields at different price points, with Monsanto's implementation evidently losing market share to cheaper seeds.[42] Oppositional discourse in both Brazil and India centered monopoly and dependence – characterized in both cases by the internationally prevalent characterization of "suicide seeds," or "seeds of death" -- and targeted Monanto specifically. On the ground, Monsanto looked more like Gulliver than Goliath, biosafety law more aspiration than constraint. "GMO-free zones" declared by popular organizations and governmental institutions would seem to be fantastical.

It is true that Brazil and India present special difficulties for environmental regulation: authority is divided structurally between center and states in expansive federal political systems with long porous borders; significant power resides in multi-tier Courts; farmers are courted by democratic regimes; bureaucracies are not immune to special pleading.[43] Yet one can find comparable characteristics militating against enforcement in many political systems: penetrated or captured regulatory agencies, corruption, bureaucratic incapacity, local power of the nominally regulated. Surveillance of nature is no mean task, either macro or micro.[44] There are no phenotypic markers to differentiate transgenic plants from isogenic varieties, or at least none within the skill repertoire of modal bureaucrats. Gene police will be hard to come by in the villages. The discourse of Cartagena on international norms of biosafety for "living modified organisms" could well prove to be more symbolic politics than real barrier to gene flow – but will necessarily raise costs and slow development of new technology. If the benefits of these crops are captured by a subset of farmers and seed companies, but the costs are spread to society generally, the case for transgenics is proportionately weaker on developmental grounds.

In the optimistic narrative, state technicians will be able to make for society the cost-benefit analyses necessary to decide which transgenics, when, and where. But there are also no probability distributions from which a true risk assessment can be derived and few imaginable means of stopping the flow of seeds that farmers want – short of the terminator. There is no dispute that the regulatory regime of the Cartagena Protocol on Biosafety of the Convention on Biological Diversity will be costly and difficult to implement, particularly in the poorest countries, and perhaps ineffective. The opportunity costs of implementing this regime are high in terms of brain-power, skills and funds. If transgenics represent progress, caution or "regulatory excess" has high costs for the poor. In the foreword to the Nuffield Council on Bioethic's report (2004), Chairman Bob Hepple argues: "It cannot be responsible to render a technology unavailable to those

[42] On the outcome, Sahai 2002; on political process, Ch 7 of this volume; on farmer choices, Ch 8.
[43] Both cases are discussed in later chapters; on India, see also Sahai 2002; on Brazil, Paarlberg, 2001, Ch 4.
[44] James Scott's views of state needs for visibility in **Seeing Like a State** l998 point to one of the diagnostic astigmatisms of what he terms high modernity.

whose needs are urgent. Nor can it be responsible to be partisan in a debate where empirical evidence should be decisive in settling the question." It would be convenient if a) empirics could settle the major issues and b) if empirics were decisive drivers in biopolitics.

Biopolitics:

Whether or not transgenics can be incorporated into pro-poor development strategies depends on widely shared assumptions: an appropriate intellectual property regime, bio-safety controls for environmental protection, suitable price regimes. A more important assumption, seldom explicitly stated, is that pro-poor strategies are politically feasible. NGOs speaking on behalf of the poor have intermittently blocked or destroyed field trials designed to find out whether or not there is environmental threat. This phenomenon illustrates absence of even the most basic epistemological and methodological grounds for resolution of the politicized science of "GMOs." The political vulnerability of genetic engineering is the acknowledged incompleteness of any firm estimate of risks. Uncertainty is the most powerful political weapon of the anti-transgenic movement. First, the elision of and escalation from uncertainty to anxiety meets little cognitive resistance. Fearing the unknown is not only a first response, but to some extent the rational response. Second, there is no way for science to prove a negative: that some effect will not happen (Pinstrup-Andersen and Schiøler 2000). One cannot, for example, imagine the evidence that would convince anyone that transgene flow will not cause major ecological damage somewhere, sometime. Real science is evitably, often radically, incomplete. High anxiety with low information is the condition most likely to generate the powerful effects of symbolic politics (Edelman 1962). Where ecological science is inevitably incomplete, opponents of transgenics have had ready answers.

There is thus introduced a deep indeterminacy into biopolitics: science is a powerful cognitive filter that stands between structure and interest. Science continually presents new challenges to the way interests are understood by citizens and political classes that control states; the sea change in redefinitions of interests introduced by the atmospheric science of ozone holes and climate change is archetypal. Counter-intuitive links between refrigerator gases and skin cancer were not on the agenda of citizens in the pre-Montreal Protocol days; there was a time when climate change was on no one's political horizon. Transgenic organisms represent a particularly compelling instance of these dynamics. Ecosystem health, biodiversity, allergenicity, gene flow -- all are sufficiently removed from ordinary conceptual and practical knowledge of most people that reliance on experts, or congealed knowledge, or persuasive framing, becomes inevitable. Effects take a long time to become apparent; causality in over-determined chains of dynamics is difficult to parse. And the science keeps changing. Interests in nature are knowledge-dependent, but the knowledge is constantly in flux at the margins.

Pharmaceuticals have created a spectacle of political science for mass publics utterly uninterested in science, but deeply interested in health. Because science is expensive, what will be found out depends in part on who funds what research, and how much of whatever is found is suppressed or ignored: consider the fatal catastrophe represented by Merck's Vioxx, discussed previously. Suspicion of instrumental science runs deep. NGOs in India demanded the field-trial data on Bt cotton vociferously while simultaneously telling anyone who asked that no one would believe the data if released – it was after all produced by a state that was promoting biotechnology, by scientists whose careers depended on the results and by commercial interests with profits at stake.[45] In the emergence of new interests at the frontier of knowledge, science itself loses its comfortable mantle of objectivity. There are potentially high stakes in small findings -- hence the restrictions on international field-work for fear of biopiracy, or the burning of agricultural field trials. More politically contentious, the value of these new commodifications themselves are dependent on social acceptability of the enabling science that certifies safety of products and procedures.

The genomics revolution creates possibilities for conversion of nature to property on a scale unimaginable a generation ago (Tanksley and McCouch 1997). There is a profound question of social justice in thinking about property in nature: whether or how those who have forgone benefits from the destruction of nature by leading impoverished but low-impact lives might benefit. This potential for a time seemed to alter the biopolitics of conservation, giving nature itself tangible value. So long as biodiversity is valued only in normative terms, as a desirable thing, its political base is fragile, everywhere in the world. But valuable genetic information may depend on actually existing biodiversity – or not, the science is unclear. Development of biotechnology as a sector potentially valorizes, perhaps remunerates, local knowledge, which is everywhere in danger of extinction (Gupta, l998; Weiss and Eisner l998). It builds on the human capital in science nurtured at great cost over decades in low-income countries. Use of genomics in probes for and classifications of biodiversity enormously enhances the precision of conservation policy, perhaps to the benefit of current human victims of blind preservationism that sets aside whole landscapes for lack of better information. In the contentious politics surrounding that normative spectrum from "biopartnerships," to "bioprospecting" to "biopiracy," there is an assumption that variable relationships between value and new forms of property are worth contesting (Svarstad and Dhillion 2000). Yesterday's pest could harbor tomorrow's miracle gene. Who is opposed to a cure for cancer? Via this knowledge-based revaluation of nature, a certain monetary incentive is thus introduced into the political struggle to prevent wholesale destruction of ecosystems. For a while, the Environment Minister had something to say to the Commerce Minister when the question of opportunity costs of conservation surfaced.[46]

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[45] My experience with Bt critics; see also Bharathan 2000. Mark Winston, himself a biologist, found that secrecy of the firms dealing in transgenics was a major source of distrust outside the firms, but was experienced as an imperative by the holders of inside information (2002).

[46] After the famous Merck-INBio deal's novelty wore off, however, this prospect has decidedly dimmed. On the optimistic scenario, see Gupta 1998; Reid 1996; Weiss and Eisner 1998. On the economics of why bioprospecting did not take off, Simpson et al, 1996.

Because the poor are unlikely to be politically powerful, for the many obvious reasons, coalitions become critical (Herring 2003; Moore 2003); these coalitions in the sphere of biotechnology are mediated by political science. The PT government of Brazil divides internally on the status of transgenic soy; NGOs and farmer organizations claiming to represent the poor in India are deeply divided on the question of Bt cotton. The great irony of the Indian transgenic seed story is that seed saving – a major objective of the NGOs hostile to transgenics, such as Vandana Shiva's *Navdanya* -- has become a strategy of Bt cotton farmers in India, as it has of Brazilian transgenic soy producers. Had the seeds been "terminators," as often claimed by the opposition, this outcome would have been impossible. Monsanto's operation in India did not crush farmers, as NGOs said it would, but rather seems to be losing market share with its expensive seeds.[47] Home-grown agrarian anarcho-capitalism proved to be effective competition for multinational technology. It is not clear that Monsanto can recover its development costs, much less innovator rents. When the BBC characterized Navbharat's appropriation of Monsanto's Bt gene construct as "biopiracy," the rhetorical tables were turned; the assumption that genetic flow can move only upstream, from South to North is clearly problematic. Loss of legitimacy on the part of the small segment of the politically active who claim a pro-poor agenda cannot further the cause.

Ideologies incorporating junk science have a clear tactical political advantage, but risk legitimacy in a strategic sense. The advantage derives from the core characteristics of science-as-method – skeptical agnosticism, tentative conclusions, replicability, validation in epistemic communities – commitments at odds with the simplicity and certainty privileged by politics. Junk science forgoes these complications in favor of reductionist explanations that evoke anxiety in spheres of low information or cognitive complexity. As science is inevitably a work in progress, and therefore incomplete, uncertain if honest – mis-recognition of interests *via* obfuscating ideologies render real science politically vulnerable. A claim in real time that UN food shipments to Africa are "poison" will get a precautionary response; it is quite a different matter to assess the probabilities that some novel proteins may prove allergenic to some people at some time. As we have long known, anxiety is the condition under which we expect the most powerful effect of symbolic politics (Edelman 1962), which is the terrain of narratives.[48]

Development Frontiers:

Despite Michael Lipton's caution that the "hype-line" is sometimes confused with the "pipeline" of new technology, there is a great deal at the frontier. Thies and Devare discuss how rDNA technology is being used to create crops resistant to abiotic stresses such as drought, soil acidity, and salinity; modifications such as improved storage

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[47] Mahyco knows its seeds are being saved and replanted, but is not greatly concerned; F2s of hybrids seldom breed true, and the market will segment, they believe. Mahyco-Monsanto does not force farmers to sign contracts pledging not to save seeds, unlike the situation in the US and Canada. See Chapter 8.

[48] Edelman 1962 on anxiety and symbolic politics; on dimensions of environmental narratives, Dryzek 1997.

stability, delayed ripening, and other changes to increase flexibility in distribution, reduce waste and facilitate processing for greater market value. Advances in resistance to abiotic pressures could stablize and increase yields of crops grown in marginal, low-productivity areas to which the poor are often consigned. Increased storage stability and delayed ripening will disproportionately benefit those with little market holding power or resources to invest in storage and transport facilities.

Because of the seemingly limitless potential of genetic engineering, development discourse has placed too much emphasis on the seeds themselves: whether "miracle seeds" or "suicide seeds." Alleviation of the life-limiting conditions of poverty cannot rely on technical change alone. Michael Lipton rightly warns: "There is, indeed, a case against 'loading labour absorption or employment generation on plant breeding.'" Howarth Bouis reminds us that the "sustainable solution to micronutrient malnutrition in developing countries is a substantial improvement in dietary quality by higher consumption of pulses, fruits, vegetables, fish, and animal products, which the poor need and already desire, but cannot presently afford." That is, the primary causes of poverty, and therefore solutions, lie in property and income distribution as affected by social safety nets and transfers. Seeds cannot carry too much of the load when public policies are biased against the poor. Pray and Naseem conclude: "biotechnology research by itself cannot eliminate poverty and food insecurity. It can only be effective in delivering the benefits if all the ingredients for sustainable economic growth are present—namely good institutions and governance, sound macroeconomic policies and human capital to take advantage of the technology."

The question for development policy is always one of alternatives: compared to what? The emerging consensus among development professionals is that more public-sector funds should go into biotechnology, in part to insure that the needs of the poor are met. But what returns at the margin would justify more international development funding of transgenics? At the cost of what other projects? It would be easy to argue that biofortification research is more likely to aid the poor than projects constructing social capital or democratization or any number of amorphous and trendy sinkholes for monies that satisfy the cyclical imperatives of funders and fundees. But what of research on invasive species and ecological decline, fresh water provision – or agroecology? The frontier issue is opportunity costs at the margin: what is the best use of the additional dollar?

The first ethical dictum of development policy is to do no harm. Yet we do not yet have a consensual metric to determine how cautious is cautious enough, and how much caution is too costly? Consider the problem of scale. Agroecologies vary from *taluk* to *taluk* in India, even from village to village, but are nowhere fully mapped. Does a biosafety regime require testing across all ecological variations, or is rough comparability enough? The Nuffield Council on Bioethics recommends the sharing of methods and data between countries that have similar agroecologies (2004:73-75). But surely this recommendation begs the question: how similar? Rajasthan is something like Texas, sharing acacias and low rainfall, but is quite different in other ways. It would be a stretch to use Texas data for Rajasthan, but does one test *taluk* by *taluk*, village by village? For how long? If we knew what exactly in the ecology needed to be matched up, we would have powerful enough theory to do away with much testing. Or, to preface Chapter 7, consider the proposition that institutional mechanisms for biosafety are almost certain to be at least partially ineffective: is the certainty of gene-use restriction technology -- aka The Terminator -- a more cost-effective answer to potential problems in gene flow? A terminator that could ensure enforcement of some biosafety regulations could simultaneously render property claims of commercial firms much more enforceable than is currently the case. Under what conditions would societies accept the Terminator?

Equally unsettled is the comparative returns on different avenues of research. Compared to spraying toxins, Bt crops fare well in terms of biodiversity in the fields, human health and crop protection. But is the relevant comparison conventional agriculture – which many believe unsustainable – or rather alternatives from organic or agroecological approaches? Norman Uphoff's chapter argues that at the margin research monies for improving genetic potential compete with superior pay-offs from agroecological research. Uphoff's data from multiple test sites across several continents on the system of rice intensification – itself subject to scientific controversy (Surridge 2004) -- suggests that there are ways to increase the percentage of genetic potential realized by plants growing under actual conditions in the field that may be superior to increasing the nominal genetic potential of the plant itself.[49] Uphoff's ecoagricultural techniques for rice are certainly compatible with rice that makes beta carotene in its grains, not just its leaves; the result would presumably be a double benefit for the poor: higher yields of more nutritious rice. But rice that makes beta carotene in seeds as well as leaves required an extraordinary feat of institutional cooperation and biotechnology, now called Golden Rice (Potrykus 2004).

One could have Golden Rice with high or low yields; one could have high SRI yields with no pro-vitamin A in the endosperm, or only in the non-edible plant parts as with conventional rice. From an agroecosystem perspective, use of herbicide-tolerant crops allows reduced and zero-till practices to work more effectively, reducing soil disturbance so as to retain more organic matter, improve soil structure, reduce soil compaction and improve soil water relations. In both cases it would then seem that the best strategy is to combine agroecological advances with transgenics, as some agroecologists recognize (e.g. MacNeely and Scherr 2003:153). Bambawale et al (2004) found that the best performance of participatory integrated pest management in their field study in India was with transgenic cotton – Bollgard 162. Devparna Roy's unpublished field investigation of organic farmers in India finds that some use Bt cotton – a transgenic crop very much contested nationally – with chemical-free cultivation techniques in accord with Gandhian values.[50] This strategy of walking on two legs is the essence of Gordon Conway's (l997) "doubly green revolution."

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[49] See also Uphoff 2002; 2003; Uphoff et al 2002; for a broader view, McNeely and Sara J. Scherr 2003.

[50] They do this, Roy finds, of economic necessity: returns are higher and "they have to feed their children." Roy, personal communication; see also "Adoption Paradoxes of Bt Cotton in Gujarat, India" forthcoming.

There is but one problem with this sensible conclusion: the unresolved issue between Prometheus and Pandora. In the United States, "organic" is an industry standard enforced by the federal government, and occupies an advantageous market niche that is growing rapidly. "Organic" is specifically defined to exclude "GMOs." Yet the objectives in transgenic crop engineering and organic farmers in reducing soil erosion, synthetic chemical inputs and destruction of helpful insects are congruent. To the extent "GMO-free" remains a meaningful market category, the threat of gene flow financially escalates. It is precisely poorer farmers that have the lowest opportunity costs of labor and can engage in labor-intensive practices associated with chemical-free agriculture. This market niche is thus of some importance to the world's poor farmers, so long as rich consumers prefer organic produce and are willing to pay the premium. In this case, the externalities of transgenic crops are anti-poor, but only so long as the categorical rejection of a new form of plant breeding remains meaningful in the market. This bright line distinction between recombinant DNA and other forms of moving DNA around plants undermines an otherwise sensible complementarity.

Whether or not genetic engineering constitutes a fundamental break in manipulation of plant genetics represented by thousands of years of breeding depends on a more fundamental cognitive divide that is ontological and not movable by appeals to the data. This is a divide between an *organismic* view of nature and a *molecularist* view. From the organismic perspective, putting a fish gene into a tomato – a popular hoax used by opponents of genetic engineering, but not an inconceivable outcome -- violates some threshold of the unnatural. For the pure molecularist, there are no fish genes or tomato genes, just variable organizations of bases in DNA, arranged in different networks: all life is composed of the same stuff, just differently arranged, and the arrangements are largely accidents of evolution. In the organismic view, species constitute the natural world; to disturb this order is to assume the thoroughly unnatural position of "playing god." This is a global construction of the case against transgenics. Anil Gupta counters the view of many public intellectuals in India with the observation that farmers have no problem with Bt cotton: "Indian cosmology is quite comfortable with porous and ambiguous species boundaries: just see our beloved god Ganesh, half elephant, half human."[51] In the end, political outcomes in contestations of transgenic crops, like those in embryonic stem-cell research and cloning, depend more on theological and ontological dispositions than on science. Whether or not rDNA technology for the poor is in the public interest or not depends on how one conceptualizes the public, how one couches the alternatives, the normative position one takes on uncertainty and risk, and the projections one makes from an inevitably incomplete science.

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[51] From remarks presented to the Workshop on Development, Governance and Nature, Cornell University, November 16, 2004, entitled: "Bridges Between Big Science and Little Science."

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