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Neoliberalism on the molecular scale. Economic and genetic reductionism in biotechnology battles

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Abstract

New agro-biotechnologies promise bounty from fine-tuned molecular manipulation of food crops. They already provide profits and export opportunities to a few transnational seed/ agrochemical/ biotechnology firms. Against growing resistance in international arenas, industry and US government spokespeople have aggressively promoted genetic engineering, arguing that it permits precise control of life processes. However, this claim is based on a deceptive form of molecular-genetic reductionism which uses outdated notions of "genes" and "genetic codes" and disregards the interactions among molecules, organisms, their environments, and their social settings. This discourse, in turn, supports economic-reductionist arguments that genetic information should be patentable and that market-based management of biotechnology will benefit everyone. This double reductionism furthers the extension of the commodity realm to the molecular level. It treats biotechnology inputs (genetic resources) and outputs (transgenic products) as ordinary, tradable factors of production under globally standardized intellectual property regimes and bolsters proposals to regulate biotechnology under the World Trade Organization. Critics of this approach find some support in the Biodiversity Convention and its Biosafety Protocol, which would allow consideration of scientific uncertainty, socioeconomic factors, and pluralism in intellectual property regimes. They stress that natural-resource values and knowledge about nature are inseparable from place-specific ecologies, cultural practices of farming and science, and power relations.

Keywords: Biotechnology; Agriculture; Intellectual property; Genetic resources; World Trade Organization; Convention on biological diversity

1. Introduction

The past five years have seen heated international disputes about the patenting of genes, crop varieties, and genetic engineering techniques, about trade in biotechnology products, and about control of the world's "genetic resources"—the raw-material inputs for medical and agricultural biotechnology. These biotechnology battles are being played out in the World Trade Organization (WTO), the UN Food and Agricultural Organization, the Conventional on Biological Diversity (CBD), and other international arenas. The United States government, intent on reinforcing the dominant position of its own biotechnology-based industries, has fought hard for the acceptance of genetically engineered crops, for liberalization of biotechnology trade, and for the worldwide standardization of private intellectual property rights to biotechnology and its products.

Private-sector positions and US policy in these global fora are framed by a neoliberal approach to biotechnology regulation. This approach, I contend, depends upon two forms of reductionist discursive practices: molecular-genetic reductionism and economic reductionism. Economic-reductionist arguments are mobilized in international debates to support the private ownership and market-based management of biotechnology and the interests of biotechnology firms. These arguments, in turn, make use of genetic-reductionist representations of "genes" and "genetic codes". However, such representations are supported neither by the theories and practices of contemporary molecular biology nor by the actual experiences of scientists and farmers who work with genetically modified organisms.

The discourse of molecular-genetic reductionism postulates specific traits that are "caused" by one or more "genes", whether in humans or fish, bacteria or

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corn. It conceptualizes genes as discrete entities: functional units of information which can be characterized precisely, counted, added or subtracted, altered, switched on and off, or moved from one organism or one species to another by means of genetic engineering. The metaphor of the determinant "gene", although appealing in its simplicity, is seriously misleading. Nevertheless, the notion of "genes" as unitary objects with stable, predictable properties provides conceptual support for treating genetic constructs as tradable commodities which are subject to market exchange and to the assumptions of neoclassical economics.

The dominant paradigm of environmental resource management attempts to incorporate nature within this neoclassical economic framework, emphasizing the role of markets in the valuation and allocation of natural resources, including genetic information (Costanza et al., 1997; Dixon/World Bank, 1997). The values of nature are equated with the prices, in actual or hypothetical international markets, of natural resources such as timber and medicinal-plant samples and of ecosystem services such as tourism sites, CO_2 sequestration, and water filtration. This approach is reductionist in that it treats nature and its components as quantifiable and as separable, at least conceptually, from their contexts in living nature and society, while it obscures the effects of political, cultural, and ecological factors on market transactions and resource values.

The two discourses of economic and molecular-genetic reductionism are linked and mutually reinforcing in multilateral policy debates. Doubly reductionist representations of genetics and biotechnology are mobilized by those stress biotechnology's scientific status and advocate minimal biotechnology regulation and globalized intellectual property rights (IPRs). Such representations are critiqued by those who stress the risks and limitations of technological solutions to problems of hunger and poverty and the need for policies that are specific to particular ecosystems, socioeconomic conditions, and local and national development strategies.

Disputes over these issues have embroiled multilateral fora, especially the WTO and its Agreement on Trade-Related Intellectual Property Rights (TRIPS), the CBD and its new Biosafety Protocol, and the 2001 international Treaty on Plant Genetic Resources for Food and Agriculture. These disputes involve shifting alliances among the US and European and developing countries, tensions between social movements and states, and collisions between emerging institutions of environmental and economic governance. More than biotechnology per se is at stake: conflict over biotechnology has become a flashpoint of resistance to globalized governance under US hegemony.

Section 2 of this article critiques the arguments employed in these debates by those who advocate biotechnology as the key to global food security. These arguments, I maintain, both depend upon and foster disingenuous technological optimism and an idealized view of nature and biological science: molecular-genetic reductionism. They employ the tropes of the "genetic code" and the unitary "gene" in a way that oversimplifies the relationship of genetic information to the traits and behaviors of organisms. Section 3 cites preliminary evidence, drawn from recent scientific studies and farmers' experiences, that suggests that this discourse also relies on a limited and biased selection of empirical results.

Section 4 summarizes the disputes over biotechnology and related intellectual property in institutions of global governance. I show how government and biotechnology industry representatives have combined economic and genetic-reductionist ideas in their arguments against biotechnology regulation, and describe how the US positions on biotechnology and IPRs are tied to international economic goals and the interests of transnational agrochemical firms. A final example, Section 5, notes the double reductionism at work in the defense of proposed new "terminator" technologies that would engineer plants to produce sterile seeds. The conclusion highlights the incompatibility of the abstract, universalizing categories of neoliberal trade and environmental policy with the diversity of living biological variety and real-world agricultural and eco-social systems.

2. Molecular-genetic reductionism and the idealization of biotechnology

2.1. The myth of genetic-engineering "precision"

Although they apparently involve very different substantive content, economic and genetic reductionism share the same fatal flaw: abstraction from the spatial and temporal specificity of nature and from the environmental and social contexts in which nature coevolves. Agriculture in particular cannot be understood separately from the specific ecological and social situations in which it is carried out.

Advocates of agricultural genetic engineering maintain that it will benefit farmers, consumers, and the environment worldwide by increasing the quantity and quality of food grown, reducing the need for hazardous pesticides, and lowering costs. According to Monsanto scientist-entrepreneurs, the new biotechnology can substitute "information-intensive" techno-science for the slow, trial-and-error plant breeding and the polluting practices of industrial-era farming. Such arguments draw upon vague notions of a post-industrial "new economy" which, almost miraculously, creates values from information with relatively little need for mundane material inputs or labor (e.g., Horst and Fraley, 1998).

Predictions of huge agro-economic and ecological benefits from transgenic crops—those containing genetic material from other varieties or species, inserted by genetic engineering—also depend heavily on the discourse of molecular-biological reductionism (Horst and Fraley, 1998; Miller, 1997). Proponents of crop genetic engineering convey the impression that, thanks to new techniques for mapping and manipulating genomes, bioengineers always know exactly what "gene" they are moving from one organism into another, just how that bit of DNA will act in the new organism, and exactly what expressed trait or behavior will result from the DNA or RNA transfer. The Biotechnology Industry Organization public relations campaign explains:

> Through modern methods found in biotechnology, researchers can accomplish the desired results, but in a more *efficient and predictable* manner (than in conventional plant breeding). In this process, a *specific gene, or blueprint of a trait*, is isolated and removed from one organism then relocated into the DNA of another organism to replicate that similar trait. (BIO, 2001: www.whybiotech.com; my emphasis)

The "gene" is represented here as a transferable unit of information that will produce specific, known traits in its new host organism. This representation is linked to the notion of an all-determinant "genetic code", a trope which connotes linear causality and an implicit comparison with computer software. These discursive constructs bolster the idea that the ability to "decode" genomes and insert new "genes" now enables science to "reprogram" life: to eliminate most disease, if not mortality, and to devise super-crops that will bring about the end of hunger.

2.2. The obsolete concept of "the gene"

However, the claim that molecular genetic engineering permits accurate control of life processes is based on a deceptively simplistic representation of genomic technoscience and of the role of "genes" in the development of organisms. There is growing appreciation among scientists of the exquisitely complex and only partially determinant interaction among genetic sequences and other cellular and organismic components and functions. In this light, the concept of the "gene"—understood as a unitary, moveable object—is becoming obsolete. While the "gene" remains convenient as a heuristic device, still indispensable in some forms of scientific reasoning and experimentation, its ontological status as a discrete, causal unit of heredity is increasingly in doubt (Beurton et al., 2000; Fox Keller, 2000). It is misleading to represent "the gene" as the fundamental (but re-programmable) functional unit of organismic development and physiology. Nor are genomes really like "code books" or "programs" that determine life processes in any simple sense (Kay, 2000).

What we call "genes" have different functions in different contexts. The effects produced by "genes" (gene expression) are the result of dynamic, continuing processes of interactions among different sites on the genome, among information from DNA and RNA and information carried by other molecules in the cell, among cells and larger-scale physiological systems and the organism as a whole, and between complexes of organisms and their geophysical environments, as well as the interactions between natural environments and their social co-determinants (Rose, 1997; Beurton et al., 2000; Bourgaize et al., 2000; Fox Keller, 2000; Lewontin, 2000). A critically important corollary is that organisms with identical genomes, genetically altered or not, will develop and behave differently in different places or under different conditions.

For example, it has long been known among scientists who work with living plants outside the laboratory that animals and plants with identical genomes—twins or clones of the same plant—grow very differently, often according to no pattern yet discernable, in response to temperature fluctuations, differing elevations, or other variations in their environments (Lewontin, 2000). The causes of these phenomena have been little-researched precisely because they do not lend themselves to easy solutions, much less to the production of patents, profitable commodities, or research funding and fame. These scientific unknowns rarely appear in discussions of genomic "enhancement", yet such variations are critically important to the actual performance of transgenic crops. Farmers in Texas and Missouri learned this the hard way when their crops of transgenic herbicide-tolerant (Roundup-Ready) and Bt (*Bacillus thuringiensis*) cotton failed during a hot growing season. Monsanto blamed the problems on "extreme" weather, but had to pay millions to the farmers in legal settlements for their losses (Hansen, 2000).

Who among non-scientists would guess—having heard the praise of genomics' "precision"—that most of the cells or embryos into which technicians attempt to insert new genetic material are killed, or are deformed, or fail to take up the new genetic construct, or carry the "gene" yet fail to express the desired trait? Even when genetic engineers know the exact sequences of nucleotide base-pair triplets —"letters" in the genetic "alphabet"—that they want to transfer to the genome of an animal or plant, it typically takes hundreds or even thousands of failed attempts to produce an organism that actually displays the desired trait, or a cloned animal that survives without debilitating deformities (Humpherys et al., 2001). Press reports about the cloned sheep dubbed "Dolly" rarely mention that 227 dead sibling embryos and deformed fetuses were discarded in the effort to create one viable clone (Darnovsky, 2000). Invertebrates and mammals have been "successfully" cloned, in the sense that apparently "normal" genetic duplicates have been produced (as well as many grotesque failures), but a large proportion of these clones have shown physical or behavioral problems at later stages of their development. In the genetic engineering of plants, standard procedures take account of the fact that in most cases, only a small proportion of the targeted cells will incorporate the DNA that technicians try to insert, and fewer of these will grow to become plants with the sought-after trait.

This miniscule ratio of success to genetic engineering attempts is quite unsurprising from the viewpoint of developmental biologists, geneticists, and genetic engineers. They know that rather drastic—although now routine—methods must be used to overcome the defenses against "foreign" genetic material that all organisms have developed in the course of their evolution. To force targeted organisms to incorporate genetic material from other species, technicians bombard plant cells with micro-pellets coated with DNA or expose cells to powerful vectors—genetic Trojan horses—engineered from viruses that can penetrate evolved barriers to the exchange of genetic material between species. They must also add "promoter" or "enhancer' genetic constructs to goad the engineered cells to produce the sought-after proteins according to "instructions" from the inserted genetic materials.

The location in the genome of inserted genetic constructs can be critically important to the expression of the new "gene". However, plant genetic engineers often have little or no control over just where in the recipient organisms' genome the new genetic material will become inserted, or how many copies of the genetic construct are incorporated, much less how the inserted constructs may interact with the organism's thousands of other "genes". Breeders of transgenic plants attempt to select engineered strains of crops with stable characteristics, but know little about the multiple effects of the inserted transgenes on the rest of the plants' genomes, especially when growing conditions vary, as the genetically altered plants reproduce, and as they interact with other organisms such as viruses and soil bacterial. In light of all this, we should hardly be surprised that the performance of transgenic crops has been erratic and that industry predictions of benefits in the form of less agrochemical use, lower input costs, and productivity gains have yet to be born out.

2.3. The troublesome trope of the "genetic code"

The idea of the genome as a "code" or "program" that mechanically spells out the letters or instructions for life, and that can be rewritten by simply adding or deleting a few commands, is inadequate to capture the experiences of most scientists who deal with living organisms. The "code" concept is even less useful for understanding the traits and behaviors of organisms in natural environments, or the patterns studied by ecologists of the how introduced organisms can alter the make-up and functions of entire ecosystems. Real life—as opposed to genetic formulae—exhibits both recalcitrance and resilience in response to interventions that attempt to fine-tune the molecular functions of organisms.

Living things are recalcitrant in the face of genetic manipulation in the sense that cells and organisms often compensate for the removal or addition of a bit of genetic information by activating alternate pathways for producing the original effects of the modified "gene" so that no change in the organism's appearance or functions is discernable (Fox Keller, 2000). Similarly, ecosystems are sometimes resilient in response to changes in ambient conditions and in the composition of their component species. By the same token, however, small changes in the genetic make-up of organisms, variations in the intra-cellular environment of genes, and changes in the conditions under which organisms develop frequently lead to major, sometimes lethal alterations in organisms, or to major and multiple changes in the composition and health of ecosystems.

Such changes are not entirely predictable, and this is so not merely because genomic science is not yet advanced enough to cope with such a high level of complexity. One reason for this intrinsic unpredictability is that there is always a degree of randomness, or developmental "noise", involved in the formation of organisms, such that an identical sequence of genetic "instructions" can lead to a range of results even under identical conditions (Lewontin, 2000). More importantly, the cell's "reading" of the genetic information in chromosomal DNA is influenced by intricate mechanisms of feedback and mutual determination between "genes", proteins, and other cellular components, which in turn are affected by feedback systems and changes in the organism as a whole. These changes, further, are subject to environmental variations, which themselves are partially a consequence of the development and activities of the organism (Levins and Lewontin, 1985).

Indeed, among many molecular geneticists, the long-revered "central dogma" of genomics has passed out of fashion. The core idea of that dogma, famously characterized by Francis Crick (1958), is that "DNA makes RNA and RNA makes proteins and proteins make us" and that information flows only in one direction, *down* from the genetic code: as Crick put it, "once the information gets in, it cannot get out". The old dogma is being supplanted by more complex views of the relationship of genetic information to the development and functioning of organisms. More contemporary explanations try to account for the impressive abilities of cells and organisms to resist "re-programming" and for their self-regulating and self-repairing capacities. In addition, biologists and ecologists alike increasingly recognize that organisms and ecosystems display emergent properties that appear at levels of greater complexity and later moments in time and that cannot be calculated linearly from their component parts and precedent stages (Rose, 1997; Fox Keller, 2000; Manson, 2001).

A certain amount of scientific hubris has been deflated by the results of the "cracking" of the human "genetic code" in February 2001. [1] The deciphered human genome, it had been said, would soon provide the keys to genetic cures for most of what ails us. It has gradually become clear that the DNA/RNA "master code" for amino acid synthesis in nearly all genomes, first translated in 1967, accounts for only a small part of what we need to know in order to manipulate genomes in benign ways. As Stephen Gould pointed out, the list of human "genes" is only one-third longer than that of a tiny, transparent worm with only 959 cells (Gould, 2001). The number of our "genes" is far too few to provide individual genetic instructions for each of the proteins produced by the human body, much less for the intricately choreographed, four-dimensional interactions among proteins and other cellular components.

Billions have been invested in biotechnology stocks on expectations bolstered by the genetic-determinist representation of the genome as the "book of life" with "genes for" this or that trait or disease. However, after 16 years of research and clinical trails, not one form of gene therapy has yet reached the stage of non-experimental commercialization. The recent sequencing of the human genome, however useful for continuing research, has not unlocked the key to the predicted plethora of profitable cures. To entice new venture capital to biotechnology, biotechnology entrepreneurs need a new holy grail, said to be just over the next R&D horizon. Their emphasis has shifted to "proteomics", or "functional genomics", by means of which they promise to apprehend organismic complexity by subjecting genome and protein libraries to modern systems theory and the computational powers of information technology. But the paradigm of proteomics is no less one of molecular-genetic reductionism, with its belief that the whole can be understood by analysis of its individual parts.

An alternate view is that parts cannot be understood except in the context of the whole, living organism, developing and evolving in continuous, dynamic interaction with its environment, and altering that environment in the process (Levins and Lewontin, 1985; Rose, 1997). While not all geneticists and ecologists share this dialectical view of organism–ecosystem relations when it is stated abstractly, ecologists are likely to have learned from experience that ecosystems change when the organisms that comprise them are altered, and that when an ecosystem changes, so does the organism being studied. This is just what has happened in the case of the genetically engineered crops which have been planted commercially, mostly in the United States, since 1996.

3. The strange fruits of genetic engineering

Scant public funding has been dispensed for the study of transgenic crops; documentation of the performance of the varieties that were rushed to market in the second half of the 1990s is only now being published (Benbrook, 2000; Gregory et al., 2001). Already, however, these little-publicized findings indicate a pattern of mediocre and inconsistent crop performance and unpredicted effects that contrasts with the idealized image of agricultural genetic engineering as capable of increasing food production in an exact, ecologically safe, and economically sustainable manner.

Among the problems reported so far are lower-than-predicted yields and higher-than-predicted pesticide costs. Genetically "enhanced" crops do not always perform better than similar conventional varieties, and when they do, they are only marginally superior (New Scientist, 1999; Benbrook, 1999, 2000; Hansen, 2000). Yields of genetically modified soy beans have not matched those of non-genetically altered types (Carpenter, 2001; Benbrook, 1999, 2001; Elmore et al., 2001). Plants altered to withstand glyphosate sometimes die or are harmed when sprayed with Roundup (Hansen, 2000). Crops engineered to produce Bt insecticides sometimes fail to produce enough poison to kill their targeted herbivore pests (Hansen, 2000; Letourneau and Burrows, 2001). Higher-priced maize varieties with Bt toxins built into their tissues turns out to be not worth the extra cost to farmers except in occasional seasons of very heavy infestation (Hyde et al., 1999).

In only one crop, Bt cotton, have growers who switched to genetically engineered varieties been able to reduce the total volume of their pesticide applications (Benbrook, 2001). However, there is reason to expect that this economic and environmental gain is only temporary. The spraying of glyphosate and similar herbicides on crops genetically engineered to tolerate them opens an ecological space in which weeds with the ability to grow in the presence of those herbicides can multiply (Altieri, 1995; Freudling, 1999; Benbrook, 2000; New Scientist, 2000). Weed resistance has already become a serious problem for farmers in Saskatchewan (CBC, 2001; MacArthur, 2000). US Department of Agriculture data indicate that slightly more, not fewer, applications of herbicides are used on Roundup-Ready and conventional soybeans, and that herbicide use on

[1] The publicly funded Human Genome Project and the private company, Celera, jointly announced the sequencing, albeit incomplete, of the human genome. The two enterprises concurred that the number of human "genes" is only 30,000 or so, comprising just over 1% of our DNA. However, of the approximately 30,000 "genes" identified by each of the two projects, only about 15,000 were the same on each list.

genetically altered soy fields is gradually increasing (Benbrook, 2001). [2] Similarly, insect strains that are not vulnerable to the Bt toxins produced by genetically engineered corn, soy, and cotton can evolve and become prevalent in Bt crop areas in just a few seasons (Altieri, 2000; Rissler and Mellon, 1996).

3.1. Predictable problems of transgenic crops…

The major crop biotechnology firms, which are also the major leading manufacturers of agrochemicals, anticipated this development of pest resistance but have had limited success in coming up with new varieties and herbicides to cope with the problem. Indeed, crop genetic engineering has fueled the preexisting "pesticide treadmill" by extending the narrowly focused, technological-fix approach of earlier generations of crop breeding. Many companies profess to be pursuing more effective, multitactic, integrated pest management methods, but this is not a high-priority problem for the private-sector-dominated biotechnology research complex (Altieri, 1995; Clark, 1999; Benbrook, 2000). Rather, the pesticide-based farm management approach is advantageous to the major agrochemical/biotechnology conglomerates because it further boosts sales of transgenic seeds, the chemicals they are engineered to depend upon, and the new chemicals devised to replace those to which pests evolve resistance.

Other detrimental environmental effects of Bt crops include damage to "non-target" species. The killing of Monarch butterfly larvae by Bt corn pollen has been documented and its significance debated, but it is only one small example of the sorts of environmental disruptions that may occur, possibly with cascading effects on food chains, and that may not be evident in the short time frame of one planting cycle. [3] Among the least understood are changes in soil biota—insects, microbes, etc.—which affect soil fertility and the vigor and disease resistance of crop plants. Recent research has shown that Bt toxins can "leak" from transgenic plants and remain toxic in soils (New Scientist, 1999). Glyphosate applied to Roundup-Ready crops, like other herbicides, can damage hedgerows and non-target plants that support beneficial insects and wildlife.

[2] Defenders of GE crops that glyphosate is less toxic than some of the herbicides it has replaced. However, its efficacy is already declining as tolerant or resistant weeds spread.

[3] Such ecological disruptions may not be noticeable under US Environmental Protection Agency testing procedures, which are designed to detect direct, short-term harm to animals from chemicals, not longer-term changes in plants and ecosystems caused by living organisms and genetic constructs which may multiply, become incorporated into other organisms, and travel in the environment (Ellstrand, 2001).

An additional cause for concern is gene flow among different varieties and different species of plants and micro-organisms. Just as genetic traits in wild plants and conventional crops can be carried and transferred by pollen, so can transgenes find their way to fields where they were not meant to be. This type of sexual or "vertical" gene transfer wreaked economic havoc in just a few years on farmers in the "GMO-free" canola (rapeseed) sector in Canada when fields of conventional rapeseed were contaminated by pollen that drifted from transgenic fields.

In 2001, researchers in Oaxaca, Mexico, reported "the presence of introgressed transgenic DNA constructs in native maize landraces grown in remote mountains" (Quist and Chapela, 2001, pp. 541–543). The rapid appearance of these escaped genetic constructs in 13 of the 22 local corn varieties tested, they argued, demonstrates the vulnerability of genetically diverse crops to inadvertent "genetic pollution" from distant sources. Corn genetic diversity in Oaxaca, which is part of the main region of origin of domesticated corn, is important not only to local farmers but to agriculture worldwide, since it is a likely source of traits that may be needed to cope with resistant pests and maintain future grain productivity. Transgenes that give some crop plants and crop wild relatives a survival advantage, such as Bt-based insect resistance, could deplete this genetic diversity (Stewart et al., 1997). While the methods employed by Quist and Chapela have been criticized, few of their critics discount the likelihood of significant gene flow from transgenic as well as from conventional crops: at issue is how dangerous its consequences may be to the gene pools of food crops and related wild species that may contain useful genetic material for local farmers and future plant breeding.

Another kind of trait escape—horizontal gene transfer—may prove equally risky but harder to predict or detect. It has been known for some time that microbes such as bacteria frequently exchange genetic material asexually and that bacteria and viruses can transfer genetic material to higher plants. It is plausible—some say inevitable—that genetic material from transgenes or vectors will find its way into "non-target" organisms and form novel, unintended, and possibly dangerous combinations (Tappeser et al., 1998; Altieri, 2000).

3.2. … and (predictably) unpredictable consequences

Genetically altered crops have displayed unexpected characteristics which have no apparent connection to the traits "coded for" by the inserted genes but which have caused practical problems for farmers: malformation of cotton bolls (Hagedorn, 1997), plant-stem splitting (Coghlan, 1999; Saxena and Stotzky, 2001), and increased susceptibility to fungal infection (Kremer et al., 2001). These multiple phenotypic expressions, or "pleiotropic" effects, may be related to alterations in plant metabolic pathways and, possibly, to the "silencing" of preexisting genes that can be caused by the insertion of genetic constructs (Bruening, 1998; Brown, 2000; Al-Kaff et al., 2000; Waterhouse et al., 2001). Some unpredicted traits appear to be the result of the genetic engineering process itself. Transgenic plants have exhibited odd characteristics, such as greater fertility or a greater tendency to out-cross rather than self-pollinate, in comparison to plants with identical traits that have appeared as a result of natural mutations (Meyer et al., 1992; Ellstrand, 2001).

While such unanticipated consequences are at odds with the representation of genetic "codes" as rewritable programs and genetic engineering as "precision" science, they should not be surprising when we consider just how little is known about role of the "genetic code" in the development of organisms. Only a narrowly molecular-genetic reductionist view, in which organisms are advanced Cartesian machines that can be understood by calculating the total of reactions among their molecules and atoms, would lead one to expect anything else. A more up-to-date science sees organisms as complex systems with emergent properties that are often not subject to advance calculation, and avoids idealized, categorical distinctions between parts and wholes and between internal and external causes (Levins and Lewontin, 1985). Rather than understanding development as programmed by a genetic instruction manual, it understands "genes" and organisms as mutually constructed and dynamically evolving, the expression of a continuous conversation between changing organisms and their environments.

4. Economic reductionism and the privatization of agricultural biotechnology

Advocates of crop genetic engineering assert that recombinant DNA and genomic technologies will allow precise, scientific control over the traits and reproduction of the world's food crops. In this way, they maintain, genetically engineered crop varieties can be designed to produce more abundant food and to require less agro-pesticides. While there is good reason to doubt these unproven claims, they have largely been taken at face value within the United States. However, the commercialization of transgenic crops is much more controversial outside the US, as is the privatization of crop varieties, genetic information and biotechnological knowledge by means of intellectual property claims.

US trade negotiators and biotechnology industry spokespeople have mounted energetic campaigns in international policy arenas for the worldwide adoption of genetically engineered crops and foods, for the recognition and enforcement of private property rights to biotechnology information and products, and against regulatory measures that would treat genetically engineered organisms differently than any other category of market commodity in a liberalized global trade regime. The main arguments mobilized in these efforts rely on a combination of molecular-genetic and economic reductionism, the effect of which is to further the extension of the commodity realm to the molecular level.

If, as molecular-genetic reductionism posits, "genes" are moveable objects with specifiable effects, then, from an economic-reductionist perspective, genes and genetically modified organisms can be priced and traded, so long as clear rights of ownership to genetic information and its products are established and enforced. The discursive maneuver that construes "genes" as putative commodities provides a conceptual basis for a world market in genetic information. It enables advocates of the market-based management of biotechnology inputs and products to presume that it is possible to estimate the monetary exchange values of genetic information and "genetically enhanced" crop varieties, livestock, medicines, etc. [4]

The combination of economic and genetic reductionism supplies ideational support to political efforts to incorporate biotechnology's living raw materials and genetically altered products of into a unified global trade regime. In combination with the claim that technological innovation requires IPRs, this double reductionism provides a rationale for the United States' push to bring biotechnology regulation under the aegis of the WTO and its provisions on Trade-Related Intellectual Property Rights (TRIPs). Such reasoning also underpins the argument—an argument that industry spokespeople and US diplomats have advanced in debates over international biosafety and biotechnology trade policy—that minimal state or multilateral regulation of genetically altered crops and foods is necessary because "the market" can be relied upon to sort out the bad from the good.

To illustrate the impact of this double reductionism and to uncover some of its hidden assumptions, the following subsections offer an overview of the biotechnology battles which have embroiled institutions of international governance and a critique of the discourse in terms of advocates of crop genetic engineering have pressed their case. To reveal the material interests which this discourse occludes, I then contrast the public image of crop biotechnology as an enterprise on behalf of poor farmers and the hungry with the private priorities and

[4] A wheat variety with an added gene said to cause each plant to produce 5% more than an otherwise identical variety ought to cost about 5% more than the conventional variety, and so on.

proprietary products which have dominated actual biotechnology research and development agendas.

4.1. Global biotechnology battles

Conflicts over biotechnology helped to precipitate the collapse of the 1999 WTO Ministerial session in Seattle, where many delegates decried a US-backed proposal to bring biotechnology regulation under the WTO aegis. Such as plan could have outflanked the Cartagena Protocol on Biosafety, a plan for regulation of biotechnology trade within the framework of the Convention on Biological Diversity that was then under negotiation but opposed by the United States (Canada/WTO, 1999; Boadle, 1999). Two months after the Seattle debacle, US negotiators reluctantly agreed to accept the Cartagena Protocol, which will govern the transborder shipment of "living modified organisms" (LMOs). Although the US delegation held out on some key points—mainly that shipments of genetically altered products and seeds meant for processing and animal feed will not have to be labeled as LMOs—the resulting Cartagena Protocol text reflects real concessions by the United States. [5] These events revealed a growing congruence of interests between many developing countries and most European states against the US push for rapid food trade liberalization and biotechnology deregulation.

Biotechnology is also a significant factor in the controversial US effort to strengthen the WTO Agreement on TRIPs. [6] Initiated by a transnational corporate coalition and introduced by the US, the 1994 TRIPs Agreement stipulates that WTO member states must adopt and enforce patent laws "in all fields of technology" (WTO/TRIPs Article 27.1; Cosbey, 1999; Drahos, 1999). TRIPs treats the genetic components of organisms, as well as genetically altered varieties of living organisms, as ordinary commodities subject to private ownership and standardized rules of transnational commerce. In its present form, TRIPs would make it illegal under most circumstances for citizens, businesses, or government agencies to commercialize or distribute brand-name plant varieties and privatized gene sequences, proprietary medicines, research technologies, and databases. Resistance by developing countries to this version of TRIPs has been growing and continues in the WTO TRIPs Council (ICTSD, 1999, 2000; Kohr, 1999; South Center, 2000; Third World Network, 2001).

Other WTO rules to which Southern-country collations object would harmonize the food-safety and environmental standards of member states on the basis of uniform scientific guidelines and legal models developed by the United States and the European Union. Many also oppose WTO provisions which do not recognize the principle of scientific precaution: WTO guidelines generally treat technologies as safe unless "sound science" has produced evidence that they have caused harm. Because transgenic crops have not yet been widely deployed in the global South, the possibility of future damage from such crops to the South's unique regions of crop genetic diversity would have no bearing on WTO and dispute settlement processes.

For critics of crop genetic engineering and universalized IPRs, the Convention on Biological Diversity provides a platform and an alternative point of reference to that of the WTO. While the WTO would subordinate social and environmental concerns to the overriding objectives of economic growth and liberalized trade, the CBD, at least implicitly, allows for variations in the resources and priorities of different countries and for consideration of likely differences in the impacts of biotechnology in different settings (Nijar Singh, 1996; Kenya/WTO, 1999). CBD provisions call for "fairness" and "equity" in genetic-resource exchange and for conservation of agricultural and other biodiversity in situ: in the ecological and social contexts in which crop varieties and related cultural practices have co-evolved.

The CBD, reflecting the conflictual processes by which it has been shaped since it was launched at the 1992 Earth Summit, is itself internally contradictory. Its conceptualization was influenced by a market-based paradigm of environmental management, most apparently in its endorsement of biotechnology-related IPRs, a provision insisted upon by US delegates to the original treaty negotiations. This market orientation has continued to influence interpretation and implementation of the treaty. For example, the "benefits of biodiversity", which parties to the treaty have pledged to share, are constructed in CBD documents as those benefits—pri-

[5] The main US concession is that export shipments of living (genetically) modified organisms meant to be released into the environment *will* have to be segregated and labeled (UNEP/CBD, 2000). The Protocol also refers to the precautionary principle as a valid basis upon which countries may decline to accept imports of LMOs, and approach that contrasts with guidelines that frame US technology regulation policies. Also included in the Protocol over US objections was a provision that governments may take account of socio-economic impacts in deciding whether to allow the import of particular transgenic organisms (UNEP/CBD, 2000, Article 26). Arguably, this provision conflicts with WTO rules against "unfair trade barriers" in which criteria of economic efficiency outweigh other considerations. The US delegation was also pressured to rescind its proposed treaty language that, in effect, asserted the primacy of the WTO over the CBD. Differences remain outstanding over whether and how states or enterprises will be held liable for environmental or health damages resulting from the use of their genetically modified products, over the details of requirements for the labeling, transport, and "contained use" of GMOs, and over the interpretation of scientific precaution.

[6] More than 100 developing countries endorsed proposals for the Seattle WTO session to *roll back* the TRIPs accord (Stillwell, 1999; ICTSD, 1999; Washington Trade Daily, 1999).

marily profits—resulting from the commercialization of genetic resources (McAfee, 2003). Nevertheless, for US trade negotiators and biotechnology industry lobbyists, the CBD and the Biosafety Protocol open a Pandora's box of particularisms that threaten the universal, global criterion of economic efficiency that frames the WTO regime.

4.2. US trade goals, intellectual property, and biotechnology "inventions"

Discursive representations of genetic engineering, while powerful in themselves, are linked to conflicting material interests. Material objectives clearly lie behind US efforts to achieve global standardization of IPRs through TRIPs and similar provisions in bilateral and regional trade pacts. [7] These provisions shape trade and environmental regimes so as to protect US competitive economic advantages in advanced-technology exports such as computer, consumer, industrial and military electronics and entertainment commodities (Bush, 1995; McAfee, 2003). By requiring countries to recognize and enforce property rights to drugs, food products, crop varieties and the chemicals they depend upon, as well as biotechnology tools, techniques, and expertise, these trade rules foster the expansion of established biotechnology industries, which are strongest in the United States, and raise barriers to entry against newer private or public biotechnology enterprises (Kenney, 1998; Boyd, 2002).

Agribusiness interests in the United States and other LMO-exporting countries have seen the CBD and its Biosafety Protocol as threats to their own strong position in agro-food export markets. The Protocol would permit countries to implement their own policies, based on socioeconomic criteria as well as a precautionary approach to environmental risk, on whether or not to allow imports of certain biotechnology products. US agribusiness firms have been reluctant to take on the costs of segregating genetically altered from conventional crops and would prefer not to compete with producers of "GMO-free" foods. [8] For example, should a country such as Brazil, the US' biggest competitor in international soy sales, decide to continue restricting the importing and planting of genetically altered soybean seeds, and should the Biosafety Protocol recognize its right to do so, Brazil could maintain an advantage in markets in Europe or Japan, where there is a great demand for LMO-free soy products. Under the WTO, in contrast, a decision to reject genetically engineered imports for socio-economic reasons or on environmental grounds not unequivocally justified by existing science might be deemed an "unfair trade practice" punishable by trade sanctions.

US firms and trade organizations have had a direct role in determining US international biotechnology policies, for instance, through their close collaboration with the Bush/Quale and Clinton administrations. In effect, biotechnology interests vetoed US support of the CBD on the grounds that its IPR language was not strong enough and that its provisions for transfer of biotechnology might threaten their commercial interests (Blaustein, 1996; Boyle, 1996; Busch et al., 1992; McConnell, 1996; Porter and Brown, 1996). Biotechnology industry groups have been active in pushing for TRIPs implementation and for other IPR accords (Mossinghoff, 1998; Drahos, 1999). As I have observed first-hand, company representatives have been influential consulting observers at CBD sessions and Biosafety Protocol talks. Industry lobbyists have actively influenced the US position on the newly negotiated Treaty on Plant genetic Resources for Food and Agriculture. At US insistence, treaty provisions on farmers' rights to save and exchange seed were weakened, while the issue of the patentability of crop genetic resources obtained under the terms of the treaty remains a point of contention between the US and Japan, which voted against the treaty, and the 116 states that voted for it. [9]

4.3. Does biotechnology invent life?

The US position on property in genetic resources appears paradoxical on its surface. On the one hand, US negotiators have maintained that the natural-material *inputs* for biotechnology industries are common property that should be accessible to all. According to US and other Northern-country framers of the CBD, genetic-resource raw materials such as local crop varieties or medicinal plants constitute a global open-access resource, part of humankind's "common heritage". Consequently, countries are required under the CBD to grant access on "reasonable" terms to the biodiversity in their territories (CBD Preamble and Article 15; McAfee, 2003). On the other hand, the US regards the *outputs* of

[7] Regional trade accords including the NAFTA agreement and the proposed Free Trade Area of the Americas include requirements that signatories maintain IPRs regimes compatible with those of the USA. Bilateral trade deals such as the recent agreement between the US and the government of Vietnam contain provisions requiring the new US trade partner to join the UPOV convention, which the US regards as the acceptable regime for plant variety protection (U.S./Vietnam, 2000). The US has long used promises of access to its markets under Section 301 of the 1974 US Trade Act to persuade its trade partners to adopt US-style IPRs laws (Purdue, 2000).

[8] Their lack of preparedness for this was dramatized by the Starlink corn debacle in 2000, when genetically altered corn not approved for human consumption found its way to US restaurants, supermarkets, and food export shipments.

[9] The treaty will enter info force when it has been ratified by 40 countries.

biotechnology, including engineered food-crop varieties, as private property. It has vigorously opposed CBD provisions for biotechnology transfer and benefit sharing with developing countries on the grounds that they jeopardize private property rights.

The logic behind this apparently contradictory position is bolstered by a molecular-genetic reductionist representation of the power and precision of genetic engineering. It is supposed that the greater part of the value of genetic resources, such as crop plants and the genetic information they contain, is the value that is added when those resources are "developed" by formal techno-science. The labor and intelligence employed by small-scale farmers during centuries of informal crop selection and breeding, like the contributions of nature itself, are presumed to be of relatively little worth. The "inventions" resulting from laboratory-based genetic modification of these plants may therefore, in this view, be claimed as private property, commercialized, and appropriately managed under the WTO.

Consider the link between genetic resources, intellectual property and the "invention" of medicines as depicted by former US Assistant Secretary of Commerce Gerald Mossinghoff. Mossinghoff, as US Commissioner of Patents and Trademarks, helped write the WTO TRIPs accord and later headed the US Pharmaceutical Manufacturer's Association. According to Mossinghoff, drug development and technology transfer require effective intellectual-property protection. "Without it, there really is nothing to transfer" (Mossinghoff, 1998). A pharmacologically interesting rainforest compound may be found, but it is useless until a drug company does the work of purifying, reproducing, and clinically testing the compound.

> [U]nless those three extremely expensive but essential efforts are protected by intellectual property—there would be no incentive to undertake the efforts. The compound would remain what it was when it was discovered: an interesting scientific curiosity—*of no value to anyone* (my emphasis; Mossinghoff, 1998).

The problem with this account is that the majority of commercial drugs derived from natural products have been "discovered" because they were already being used as medicines by people for whom they certainly did have value (ten Kate and Laird, 1999, p. 61). Mossinghoff's reasoning applies even less to the "invention" of brand-name crop varieties, which are derived from crop lines originally selected and improved over hundreds or even thousands of years by farming communities.

The idea that techno-science is creating "new", patentable forms of life receives discursive support from the concept of "the gene" and the myth that genetic engineering is an exact science. Now that the genomes of microbes, mice, higher plants and humans have been deciphered, industry reports suggest, scientists using advanced computers can "read" and "edit" these genetic codes. By moving and manipulating discrete "genes", biotechnology firms promise to create novel organisms with new traits. This reductionist depiction of genome "de-coding" consigns pre-genomics crop breeding and genetic research to a scientific dark age, as if plant breeders in the pre-genomics era, and especially farmers practicing so-called informal methods of crop improvement, have been toiling in ignorance and superstition. [10]

The vaunting of biotechnology as an epochal breakthrough from primitive to precision science enables its advocates to assert that its products are so unique as to justify their patenting. Those who inventively employ labor—including that embodied in advanced technology—and capital—including costly genome-sequencing machinery well as genetic information from whatever source—to create "new" organisms and data, the reasoning goes, are the proper and exclusive owners of these products of their investments. This logic helps to rationalize the privatization of science, the treatment of genetic information, organisms, bio-techniques, and research findings as proprietary commodities, and the valuation genetic resources in terms of the prices they can fetch in international markets.

4.4. Whose needs are served by agricultural biotechnology?

Biotechnology industry publicists promote the idea that the new agro-biotechnologies are being designed and deployed in the service of "humanity". The $52-million-dollar media campaign sponsored by the US Biotechnology Industry Organization (BIO) suggests that genetically engineered crop varieties are more productive and more nutritious than conventional crops and therefore hold the key to feeding the world's burgeoning population—that is, if their proliferation is not impeded by excessive regulation or scare-mongering by technology critics (BIO, 2001). This and other industry voices ignore the crucial fact that the "improved" trait engineered into at least 73% of the transgenic crops *actually being cultivated* has been the ability to withstand applications of proprietary herbicides containing

[10] Most "informal" breeders, of course, cannot describe the nucleotide sequences that help to make their rice strains more resistance to rust diseases or tolerant of drought. However, to be successful, they must apply sophisticated knowledge of varietal traits and behaviors under various ecological and weather conditions. Certainly the greatest proportion of the useful characteristics of crop plants have been discovered by farmers, not genetic engineers, with further substantial improvements achieved by public-sector plant breeders without the use of genetic engineering. (Kloppenberg, 1988).

Table 1
Genetically modified crop area by trait: pesticide-like crops dominate

Of the 41.5 million hectares sown with transgenic crops in 1999, the distribution of traits is:	
Herbicide tolerance (HT)	69% of total
transgenic acreage able to survive applications of glucosinate or glyphosate (Round-Up, etc.)	
Insect resistance (IR)	21%
plant tissues produce Bacillus thuringienis toxins	
crops with both HT *and* IR traits	7%
virus resistance (VR)	
almost exclusively Chinese tobacco	<3%

Adapted from OECD (2000).

glyphosate or glucosinate (Table 1). Such crops are neither more productive nor more nutritious, but they have substantially increased the sales of chemicals, particularly those patented and licensed by the Monsanto corporation. Far more than agronomic improvement it is economic gain, mainly from the sale of the herbicides that transgenic crops are designed to use, that has driven agro-biotechnology research and development agendas. It is giant seed/agrochemical conglomerates, much more than farmers, that have benefited (Kloppenberg, 1988; Benbrook, 2000; Boyd, 2002).

The BIO campaign rarely mentions this primary, highly profitable use of genetic engineering. Instead, it emphasizes *hypothetical*, future applications of biotechnology that promise to provide direct benefits to consumers. The emblematic project celebrated by the biotechnology lobby is "golden" rice containing pro-vitamin A, a technology that is still in the development stage and that is unlikely to be effective for its stated purpose of reducing blindness among the undernourished poor (Nestle, 2000; GRAIN, 2000; Rosset, 2001). Industry reports for public consumption emphasize the promise of this and other projected, "second and third generation" agro-biotechnology products, such as "nutraceutical" bananas engineered to make vaccines. The novelty of such technological quick fixes to vexing social problems attracts positive attention to crop biotechnology without raising troublesome questions about why so many people have lost their traditional sources of vitamin A, or why we might expect "golden rice" to reach those who need it when other food sources of beta carotene or inexpensive vitamin-A supplements do not.

Industry docu-advertisements imply that the miracles of agro-biotechnology will offset a looming global food crisis. This notion is supported by a sequence of assumptions that (a) not enough food is now produced, (b) because crops plants are not as efficient as they could be, but (c) transgenic plants will yield more, and (d) will do so more sustainably, and that (e) the additional food will be consumed by people who would otherwise go hungry. Dubious on every count, this line of reasoning links two questionable premises: exaggeration of biotechnology's achievements and the tautological, neoclassical-economic precept that optimal welfare must, by definition, result from market exchange—in this case, of biotechnologies and their seed and food products.

Some proponents of crop genetic engineering predict that new crop varieties will soon be designed to meet the needs of small-scale farmers in the global South (e.g. UNDP, 2002). This is doubtful for two main reasons. First, small farmers cannot afford "premium" seeds or the agrochemicals that those seeds require. Companies lack economic incentives to develop these or any other technologies for which there is no market, as the failure of pharmaceutical firms to invest in research on malaria and other diseases of the poor amply demonstrates. Second, small farmers may not need "premium" seeds. The limited productivity of many small-scale farms has far less to do with poor seed quality than it does with the agriculturally marginal lands cultivated by impoverished farmers, their limited access to natural manures, lack of secure tenure and markets, and their inability to afford chemical fertilizers and irrigation.

Under such conditions, the rational strategy for peasant agriculturalists is to plant a range of crops and a diversity of varieties that are adapted to local soils and micro-climates and that do not require expensive inputs or ideal weather (Altieri, 1995; Rosset, 2001). Because small- and medium-scale farmers still produce the greater part of the world's food, such agricultural biodiversity is vital to food security (Rosset, 1999, 2001; Altieri, 1995; Pimbert, 1999). Equally critical to local food security strategies is farmers' ability to save and exchange seeds and to experiment with the planting and breeding of traditional and new varieties, options which would be eliminated by the enforcement of IPR claims on crop varieties and by new biotechnologies for seed sterility (see below). The argument that private-sector-driven biotechnology research and genetically uniform, IPR-protected super seeds will address the needs of small-scale farmers ignores the real-world constraints on the "market choices" of the poor.

4.5. Genetic reductionism and the devaluation of biodiversity

To summarize: in order to feed the world by means of techno-science, the argument goes, biotechnology enterprises require globalized intellectual property regimes, without which investments in the next generation of miracle crops (and drugs) will not be forthcoming. The TRIPs agreement is said to be necessary because it requires WTO members to recognize the proprietary claims of local or foreign citizens or enterprises to brand-name crop varieties and biotechnological "inventions". Under these circumstances, we are told, biotechnological innovation will flourish and its benefits will be distributed through the global market.

However, this reasoning is shaped by a misleading combination of economic reductionism and molecular-genetic reductionism. First, it embraces the myth of the self-optimizing market world, an imaginary sphere in which all human interactions are motivated by self-interest, all transactions result in the increased well-being of both parties, and power relations play no part. Secondly, this double reductionism constructs the biological variety in farms and other ecosystems as tradable commodities. The genetic components of crop varieties or medicinal plants are deemed *more* valuable after they are removed from the places where they live and evolve (or co-evolve with human communities), and then "developed": transformed by bio-molecular manipulation and legal strategems into commercial products. [11] Thus, "genetic resources" are both conceptually abstracted and physically extracted from their local ecological and social contexts. Application of this approach to biotechnology policy permits a neoliberal argument that global free markets in the genetic-resource inputs and the genetically altered outputs of biotechnology will distribute the technologies' risks and benefits in a way that ipso facto maximizes human welfare.

The discursive move that equates the values of genetic resources with their prices in international markets reduces their value to something far less than the values of living biological variety in farms, fields, and forests. It discounts the greater part of the values of biodiversity, including locally-adapted crop varieties, to rural communities, as well as the local values of the services provided by healthy, bio-diverse ecosystems (McAfee, 1999). These values are related to the functions and uses of genetic resources in particular, place-specific eco-social systems. They are not reflected in the international market prices of genetic resources, such as the small amounts that pharmaceutical firms will pay for a batch of organic samples (Reid, 1997).

As I have argued elsewhere (McAfee, 1999), market-based pricing often involves a devaluation of biodiversity. Resource pricing based on international markets underestimates the values of living biological variety in situ. These values include the exchange values of natural and agricultural resources in local markets as well as their use-values to people who depend directly on biological resources for food, shelter, incomes, and spiritual significance, and personal and community well-being. As others have pointed out, market-based resources pricing also underestimates the values of biodiversity to future generations (Howarth and Norgaard, 1993).

Those who present biotechnology as the antidote to hunger imply that the advanced techno-science of the North produces new organisms—crop plants—that are superior in an absolute way, regardless of the ecological settings in which they are grown and regardless of the economic constraints and incentives, social goals, or cultural meanings that affect their performance and value. However, the "superior" varieties fabricated by genetic engineers are likely to be *less* valuable to most low-income farmers because they are costlier to grow and because their genetic homogeneity undermines farmer strategies for mitigating risk (Rosset, 2001).

From a neoliberal perspective, the only factors that should determine who buys what, and from whom, are market demand and relative prices (Anderson and Leal, 1991). According to this view, policies that take account of other factors—a desire for national food self-reliance and maintenance of a domestic agricultural sector, or cultural autonomy and conservation of "traditional" practices—will only introduce market distortions and permit or prolong inefficiencies. This discourse serves the economic interests of those states and corporations that are most competitive in agro-food markets, especially the United States, and the handful of firms that dominate international trade in plant biotechnology, crop germplasm (seeds and breeding lines), and agrochemicals (RAFI, 1999, 2000; Boyd, 2002).

Buttel, 2002 has argued that agricultural biotechnology, by provoking confrontations between the contrasting agriculture policies and philosophies of Europe and the United States, has become "the Achilles heel of globalization" (also see McAfee, 2003). I suggest that a further, perhaps more profound cause of this confrontation is the deep discrepancy between universalizing categories that inform the neoliberal doctrine of the WTO and "free trade" ideology, and the irreducible place-specificity of agriculture, with its rooted-ness both culture and nature. The site-specificity of organisms and their behaviors, and the immanent significance of environment in the development and identity of all organisms, is precisely what is denied by the discourse of molecular-genetic reductionism.

5. A final example: double reductionism in the "terminator" dispute

The debate over "terminator" technology illustrates how economic and molecular-genetic reductionism can reinforce each other with rather frightening consequences. In June 1999, an alliance of developing countries asked the CBD's scientific advisory body to call for a worldwide moratorium on the field testing and commercialization of "terminator" technologies. These ge-

[11] This is the rationale for the US insistence during multilateral negotiations on crop genetic-resource management that any commercial benefit-sharing arrangements be contracted at local level, before biotechnology adds commercial value by concocting a new pharmaceutical, i.e., at stage and place where world-market values are lowest. (ICTSD, 2000).

netic engineering methods—called "gene protection systems" or "genetic-use restriction technologies" (GURTs) by their advocates—are being developed by the US Department of Agriculture and commercial biotechnology firms to produce crops with seeds that will not germinate. By hard-wiring property rights into plant genomes, they would enable companies to control their privately held crop genetic resources in places where their IPR claims are not recognized or are defied, as some farmers' organizations have pledged to do.

The advent of "terminator", which confers no agronomic value to plants or benefits to farmers, has added to widespread skepticism about industry claims that transgenic crops are designed to aid the hungry and increase the productivity of poor farmers in the developing world (Horst and Fraley, 1998; Borlaug, 2000; cf. Glickman, 1999). [12] "Terminator" opponents argue that the export of such seeds would increase poor farmers' insecurity and dependence on commercial, mainly foreign seed sources, and that the escape of "terminator" transgenes might do irreparable damage to local crop varieties and their wild plant relatives. While the economic purpose of "terminator"—to enlarge seed markets by preventing farmers from saving proprietary seed—is perfectly in keeping with the letter and spirit of the WTO, proponents of a moratorium on "terminator" maintain that such technologies are at odds with CDB commitments to conserving crop biodiversity and the relevant practices of local communities.

Developing-country delegates opposed to "terminator" were in the majority when the 1999 CBD advisory body session began, but the unofficial US delegation and a few OECD states adamantly resisted their call for a moratorium. Opposition to a moratorium was spearheaded by a scientific expert commissioned by the CBD Secretariat, who advanced two, linked arguments in support of "Genetic-Use Restriction Technologies" (UNEP/CBD/SBSTTA/4/9/Rev.1, 1999) GURTs, he said, could be re-engineered so that the seeds will still germinate and grow, but will not express their premium traits unless treated with a chemical inducer which farmers would have to purchase. Farmers in developing countries, being "good businessmen", will then make a rational choice to purchase or not to purchase the superior seed, based on whether its benefits to them outweigh the added cost. In other words, he argued: release the technology and let the market decide its fate.

Both forms of reductionism are pivotal in this reasoning. First, the notion that small-scale farmers in hungry countries have unencumbered market-choice options to adopt or reject new biotechnologies is an economic-reductionist idea. It ignores the multiple ways that farmers' real-world choices are constrained by economic asymmetries and non-economic factors: lack of cash, credit, and information, the limited availability of seed varieties as farming becomes more commercialized and globally integrated, contracts that require the use of particular commercial varieties, and the heavy promotion of "miracle" hybrid and transgenic varieties.

Second, the idea that "terminator" crops can be neatly engineered so that traits can reliably be switched on and off is a genetic-reductionist claim. Hypothetical at best, it fails to acknowledge the mediocre and variable performance even of today's relatively simple, single-trait transgenic crops, much less the difficulties of designing varieties with more complex traits that would perform predictably under a wide range of conditions and that can reliably be suppressed or activated. The molecular-genetic reductionist myth of unitary, moveable, stable "genes" supports this notion, but a more contemporary appreciation of the complexity of genetic action does not, nor does the actual performance of transgenic crops to date.

The developing-country delegates to the CBD session, many of whom I interviewed, generally mistrusted the arguments put forward by the scientist-consultant, but most of them were hard-pressed to counter the claims of the designated expert. I believe this is mainly because the ideas of market-based management and scientific progress are so entrenched that it is difficult to muster the discursive resources to challenge them. [13] In the end, the majority agreed to a much watered-down statement on "terminator", but many left the session complaining bitterly about how the debate had been stage-managed.

When transgenic crops were first brought to market, industry spokespeople discounted the possibility that genetically engineered constructs would "escape" from transgenic plants to other farmers' fields or into the wider environment, much less cause harm if they were to do so. Just six years since the introduction of transgenic varieties, the reality of exactly such "gene flow" is widely recognized and the consequences of transgene escape has become a serious concern among crop scientists (Ohio State University, 2002). In a rather astonishing display of hubris, again relying on the myth of biotechnology's precision and predictability, transgenic crop advocates have seized this opportunity to argue that "GURTs" are now urgently needed precisely to

[12] The USDA has made it clear that that the main purpose of technologies for seed sterility is to protect the investments of US agribusiness firms and expand their markets. (Glickman, 1999).

[13] A few were convinced by the consultant's oddly optimistic claim that GURTs can be used to stop dangerous gene escape from transgenic fields. Some were swayed by European contentions that to slow the development of such technologies would be tantamount to blocking scientific progress. No-one wanted to suggest that their farmers were not rational entrepreneurs. A factor mentioned by several delegates was the fear of trade and aid reprisals by the United States.

prevent the spread of potentially harmful transgenic constructs. (Nature Biotechnology, 2002).

6. Conclusion

The WTO's neoliberal paradigm produces universally applicable categories and a discourse that bifurcates nature and society.“ Globalized” property regimes and techno-scientific standards, and universal measurements of resource values—such as the dollar prices of genetic resources in international markets—lend themselves to regulation under the WTO because they produce “global” criteria for managing the contents of the biophysical world. But universalizing standards of resource valuation and risk assessment occlude problems of the unequal distribution of the benefits and burdens of biotechnology, and of environmental and economic change more generally. They cannot address the question raised by Haraway of “which new beings, for whom, and out of whom” will be produced by biotechnopower? (Haraway, 1997: p. 58). Nor can they take account of differences in the impacts of agricultural biotechnology, or technology more broadly, in different ecological and social contexts.

Claims that genomic technologies and transgenic crops will benefit “humanity” ignore that their effects are mediated by social institutions, especially markets, and that they cannot be predicted without taking cultural, political-economic, and ecological dimensions into account. Among these are the power differential between small farmers and transnational corporations, and the risk differential involved in the release of transgenes on industrial-farm regions and in centers of crop genetic diversity.

Agriculture and its practices are impossible to conceptualize adequately on the basis of abstract and dualist discursive practices. Neoliberal economism and biotechnological idealism exclude, a priori, adequate consideration of the equity consequences of globalized markets in genetic resources, biotechnology, farm inputs, and food—consequences which are tremendously unequal for different nations and different communities. The introduction of “Terminator” technology, for instance, would have greatly different implications for the owners of large-scale wheat export plantations in Argentina than it would have for small-scale, mixed commercial and subsistence farmers in northern India. Nor can a universalizing approach to the regulation of biotechnology adequately assess the risks and advantages of transgenic crops because these, too, vary immensely from place to place. Introducing transgenic corn in monocrop tracts Iowa is likely to have very different consequences than release of the same transgenes in centers of maize genetic diversity in Mexico.

As we have seen, economic-reductionist discourse rationalizes the privatization and market-based regulation of the genetic-information inputs and the genetically altered products of biotechnology. It depends on molecular-genetic reductionist misrepresentations of “genes and “genetic codes” and hyperbolic accounts of genetic-engineering successes. The conceptualization of “genes” and transgenic organisms as own-able, tradable commodities, with traits and values that are independent of their ecological and social settings, also relies on a limited and misleading interpretation of the empirical results of crop genetic engineering.

The privatization of science and the growing influence of private funders on the research agendas of public institutions is steering resources toward the production of products for large-scale commercialization: profitable, technological quick fixes to complex social and ecological problems. IPR claims on biotechnology's raw materials, products, and knowledge are creating barriers to the open exchange of knowledge and scientific tools. Together these trends are inhibiting the pluralist, multipolar science and agricultural practice that is necessary to cope with the complexity and variety of agro-ecological problems in different parts of the world.

The discourse that celebrates the cracking of the genetic “code” and the precision and efficiency of genetic engineering reflects what Lily Kay called “the molecular vision of life,” a partial and particular epistemology, but one that serves the purposes of powerful private interests. This molecular-reductionist paradigm, far from being born from genomic biotechnology, has long supported the project of techno-science in support of capital accumulation in agriculture, in support of social control, and, from time to time, of explicit agendas for eugenics (Kay, 1993, 2000; Kloppenberg, 1988).

The double reductionism in terms of which privatized biotechnology is being promoted is imbricated with power relations. It embodies a bias against the inhabitants of cash-poor but diversity-rich regions, and in favor of the economic agendas of powerful states and transnational corporations. Crop varieties and medicines created and conserved by farmers and healers in “traditional” societies are constructed as humanity's “common property” to which entrepreneurs are guaranteed access. Yet nearly identical or substantially similar materials—once they have been collected, codified, and purified by formal taxonomy and techno-science—become private property governed by globalized legal and trade regimes. The same bias can be seen in the presumption that genetically “enhanced” crops developed by Northern techno-science are ipso facto superior and beneficial to the poor in the global South.

The contradictions of this discourse, and its failure to conform to the actual experience of farmers, leaves it vulnerable to challenge by those on the losing side of transactions involving genetic resources and biotechnology products. Current global disputes over agricultural biodiversity and agro-biotechnology provide an opening, a chink in the neoliberal armor, through which transnational alliances of nongovernmental organizations and Southern-country and some European governments are renewing their case against the worldwide extension of US-style intellectual property regimes and against globally uniform rules for trade, investment, and national policies on farming and food.

These conflicts have revived longstanding controversies about North–South inequality, state sovereignty, and the meaning of "development"—debates that had been expunged from the official agendas of multilateral fora by the hegemony of neoliberalism. These debates are now re-emerging as issues of international environmental justice: questions of "biopiracy" and ownership of the world's genetic resources, and questions of who, where, will enjoy the fruits and bear the risks of potentially hazardous biotechnologies. These questions in turn are linked to newer debates about the costs and benefits of globalization, the meaning of sustainable development, the right of nations and communities to determine their own food and farming policies, the understanding of environmental risk and of scientific precaution, and the powers and pitfalls of techno-science. In this context, the disputed representation of biotechnology and its risks and achievements is of great political consequence.

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