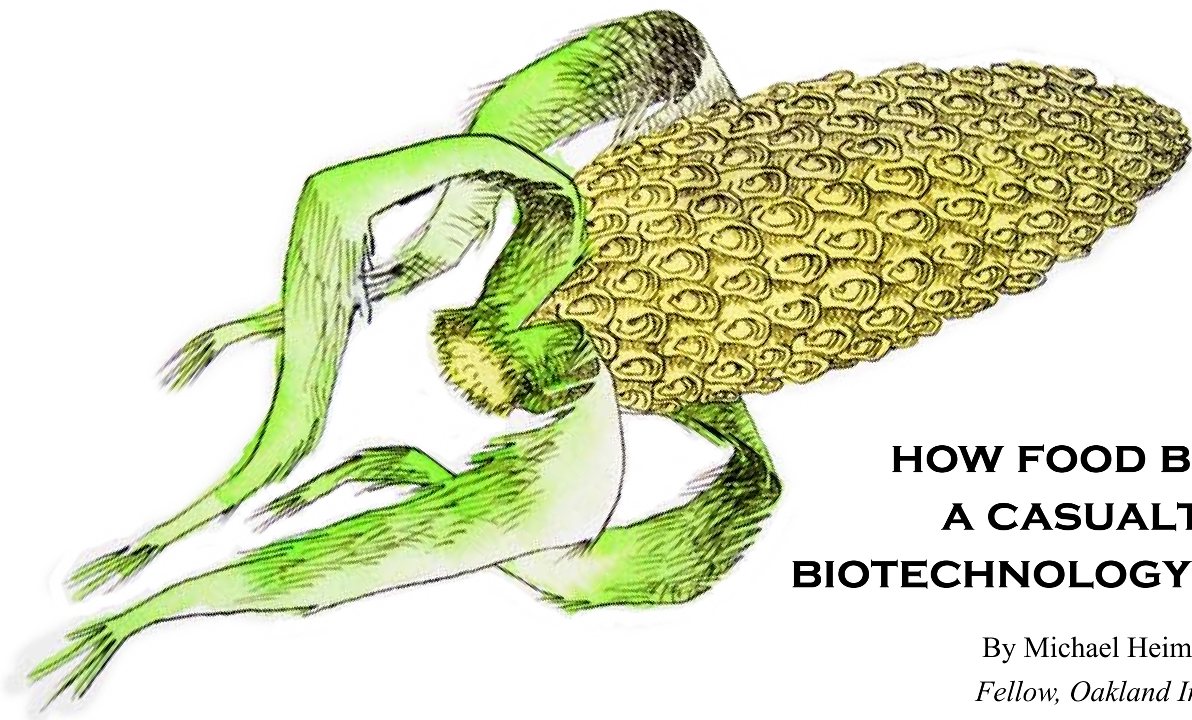
The Oakland Institute

SUMMER 2007 VOLUME 1 / NUMBER 4

POLICY BRIEF



HOW FOOD BECAME A CASUALTY OF BIOTECHNOLOGY'S PROMISE

By Michael Heimbinder

Fellow, Oakland Institute

There was something deeply mystifying about the rush of big biotech and chemical companies into the seed business, Monsanto's headfirst dive in particular . . .. It is not, in the lingo of Wall Street, a high margin business.
-Daniel Charles, *Lords of the Harvest: Biotech, Big Money, and the Future of Food* [1]

The first genetically engineered (GE) crops were approved for human consumption in the mid-1990's. Now, millions of genetically modified meals later, the clamor over GE foods has become a fixture of food policy debate. The parties to the argument generally fall into one of two camps: those who support agricultural biotechnology as a solution to world hunger and the scarcity of environmental resources and those who warn that GE crops are jeopardizing food security and threatening the environment.[2] This paper aims to establish new ground in the controversy and contribute to the groundswell of opposition against claims that "GE crops will allow us to grow more food and feed more people."

GE crops have little to do with growing food and feeding people. The developers of GE crops are not concerned with *nourishing* human life, but with *commodifying* human life. The pharmaceutical industry is investing in agriculture because plants and animals can be genetically engineered to produce human proteins and human organs – "products" that promise profits far exceeding any imaginable from high yielding crops bearing vitamin-fortified food.

The Financial Failures of Biotechnology

Monsanto, having launched their agricultural biotechnology program in the early 1980's, finally managed to release their first GE product in 1996. That is, the company spent approximately 15 years and billions of dollars before they saw any return on their investment in genetic science. This is a pattern that continues to this day: in 2006 Monsanto spent

$725 million on research and development while earning a net profit of $689 million.[3]

This is the product development model that has become institutionalized in the pharmaceutical industry. Companies spend big for several years in the hopes of coming up with a single blockbuster drug that will generate enough revenue to cover all their sunk costs while delivering a handsome profit.[4] This may be a sustainable business model for the pharmaceutical industry considering the huge size of the market – the world spent $550 billion on drugs in 2004[5] – but it hardly makes sense when addressing the traditionally low margin seed business. "Compare agriculture to pharmaceuticals; any new drug that improves a patient's health, no matter how slight the effect, can be worth billions. In agriculture, a new gene has to have the effect of a sledgehammer or no one will notice."[6] Pfizer, Monsanto's parent company, made $12.9 billion in 2006 from a single drug, Lipitor,[7] an amount double the revenue of the entire market for GE seeds.[8]

Agricultural biotechnology has been financed by the promise of future profits from products unrelated to food. As Daniel Charles notes in *Lords of the Harvest*, "Few, if any, companies that heavily invested in biotechnology for agriculture have recovered that investment through sales of genetically engineered product."[9] And this observation extends to the biotechnology industry as a whole. In its almost 30 year history, the industry has never been profitable.[10] During this time, the biotech industry has sustained cumulative net losses of more than $40 billion while investors bought close to $100 billion in stock.[11] In 2005 alone, the global biotechnology industry racked up a collective loss of $4.3 billion.[12]

Agricultural biotechnology has been financed by the promise of future profits from products unrelated to food.

Agricultural biotechnology is hemorrhaging money because they have invested enormous sums in cheap commodities – seeds – whose genetically engineered, value-added components offer negligible advantages over conventional varieties. Agriculture is an industry marked by low-margin products, high development costs, and long lead times.[13] It is not a blockbuster business and never will be because investing in products that augment farm production results in an inescapable contradiction: the demand for food is inelastic; fluctuations in price are unlikely to be met by changes in the frequency of consumption. This phenomenon, often simply referred to as the "fixed stomach," means that when supplies increase and food prices fall, consumers do not necessarily buy more groceries and eat more food.[14]

Decades of agricultural innovation have resulted in a long decline in international food prices as production has grown faster than demand.[15] In the United States, between 1913 and 1996 the real cost of food at retail level declined 35 percent.[16] The food processing industry is enormously profitable but they are not directly engaged in agriculture. The industry simply exploits their market position as the middle man between farmers and consumers, buying cheap and selling dear.[17] But the value of seeds is capped by the value of the foods they will become. Farmers will not spend more on seeds than they expect to recoup from the sale of their crops.

Seed R&D as a Means to Monopolizing Genetic Science

The meager returns from seed sales hardly matter to the giant pharmaceutical conglomerates. Food is merely a conduit through which they hope to develop and monopolize the basic technologies that will then be used to create more valuable products. As David Goodman et al. note in their groundbreaking work From Farming to Biotechnology, “The ultimate prize is domination and proprietary ownership of the scientific knowledge and process engineering technology required to control the complex biological reactions and microbial activities.”[18] These “proprietary technology platforms . . . have become the end products themselves”[19] because controlling the enabling technology is more important than owning the genetic material itself.[20] In the words of the former CEO of Monsanto, Robert Shapiro, “We are learning about biology at a level and at a rate that is absolutely unprecedented in human history. There is an enormous space to be filled, and the stakes are very high. We want to be able to occupy and hold the most valuable territory.”[21]

Leading firms such as Monsanto, Novartis, and DuPont have sought to “develop and amass patent portfolios that are broad enough to bar entry by new players and deep enough in terms of their control over basic technologies to give them substantial economic power in key markets.”[22] In a study entitled *Impact of Industry Concentration on Innovation in the U.S. Plant Biotech Industry* published in 2000, the authors found that the largest firms have been enormously successful in pursuit of these goals. Analysis shows that new firm entry in the “innovation market” is declining, and research and investment is falling in all but the top four firms.[23] Entry into the field of biotechnology is becoming increasingly difficult, as the major players jockey for position. To take but one example, in the early 90’s Agracetus was granted a patent covering all transgenic cotton. Since then, anyone making any kind of genetic modifications to cotton must seek permission from and pay royalties to Agracetus.[24]

The pharmaceutical conglomerates are investing disproportionately large sums in agricultural biotechnology because recent findings indicate that different species share similar gene constructs. For example, we share 99 percent of our genome with chimpanzees and 31 percent of our genes are interchangeable with those of yeast.[25] This discovery has given birth to projects such as the National Plant Genome Initiative which introduced the term “reference species” to suggest that the genomic map of a single plant species might serve as a “reference” for decoding the genomes of other plant species and maybe even humans.[26] As William Boyd explains in his book chapter “Wonderful Potencies: Deep Structure and the Problem of Monopoly in Agricultural Biotechnology,”

> The sequences of model organisms . . . are intended to provide the Rosetta stone of sorts for interpreting the genomes of more complex organisms. Genomics thus holds out the promise of a grand unification in biology, providing the key to the basic processes of gene function and protein synthesis common to all organisms.[27]

Biotechnology’s Promise

Biotechnology’s promise began to pay out in 1978, a landmark year for the industry. Genentech announced that it had, for the first time in history, manufactured a human protein outside of the human body. The company had successfully managed to coax insulin from an *E. coli* bacterium

by splicing human genetic instructions into its intracellular workings.

Today there are over 30 protein-based medicines on the market and an additional 371 in the research and development phase.[28] Every one of these new drugs has been made possible by advances in recombinant DNA processes and techniques. The only problem for the industry is that using single cells to produce biotech drugs, also known as biologics, is a complicated and time-consuming process.[29] These hybrid cells must be fermented or cultured in enormous 10,000 liter "bioreactor" stainless steel tanks. This presents difficulties for the smooth circulation of capital through the production process. A biotech production facility can cost upwards of $400 million and take three to five years to complete. In addition, the genetically engineered cells will only produce the target proteins if precise conditions are maintained. If the temperature, oxygen, acidity, or other variables in the bioreactor are not stable, the culture will fail. And finally, certain compounds are too complex to be manufactured using single cells.

The complications of biologics have pushed the pharmaceutical industry to pursue the promise of biotechnology in the figure of "pharming". Pharming, a coined term combining "farming" and "pharmaceutical," is the practice whereby genetic material from a foreign species is inserted into a plant or animal with the express intent of extracting novel pharmaceutical products from the resulting tissues, fluids, and organs. From 1991 to 2004 over 300 field sites encompassing hundreds of acres of land[30] and an unknown number of animals,* estimated to be in the thousands, were pharmed. The pharmaceutical conglomerates are investing in pharming because they anticipate that products that they cannot physically or affordably engineer mechanically may become feasible when the task is delegated to genetically engineered plants and animals.[31] For example, Mich Hein, the president of Epicyte, claims that his company's plant-based production technology can make the same annual quantity of drugs with 200 acres of corn and a few million dollars in expenses that a $400 million factory can produce using a mammalian cell-based system.[32]

Pharming is the ultimate pursuit for those companies performing research and development in the field of agricultural biotechnology. Billions of dollars have been invested in agricultural biotechnology, not to ensure more food or more nutritious food for the hungry, but to sell longer lives to the wealthy. Because as Robert Fraley, the executive vice president and chief technology officer at Monsanto, observes:

> There's a limit to the genes that simply help farmers grow the same old commodities . . . They're limited by the value of those crops. But think of genes that actually make the harvest more valuable! What if plants could be engineered to produce new products: oils, nutrients, or even pharmaceuticals for which consumers would pay high prices?[33]

Soon, a few animals in a laboratory will be more valuable then all the livestock in all the coops, pens, and stockyards of the world. Think genetically engineered pigs incubating human hearts.[34]

* The FDA does not make this information publicly available.

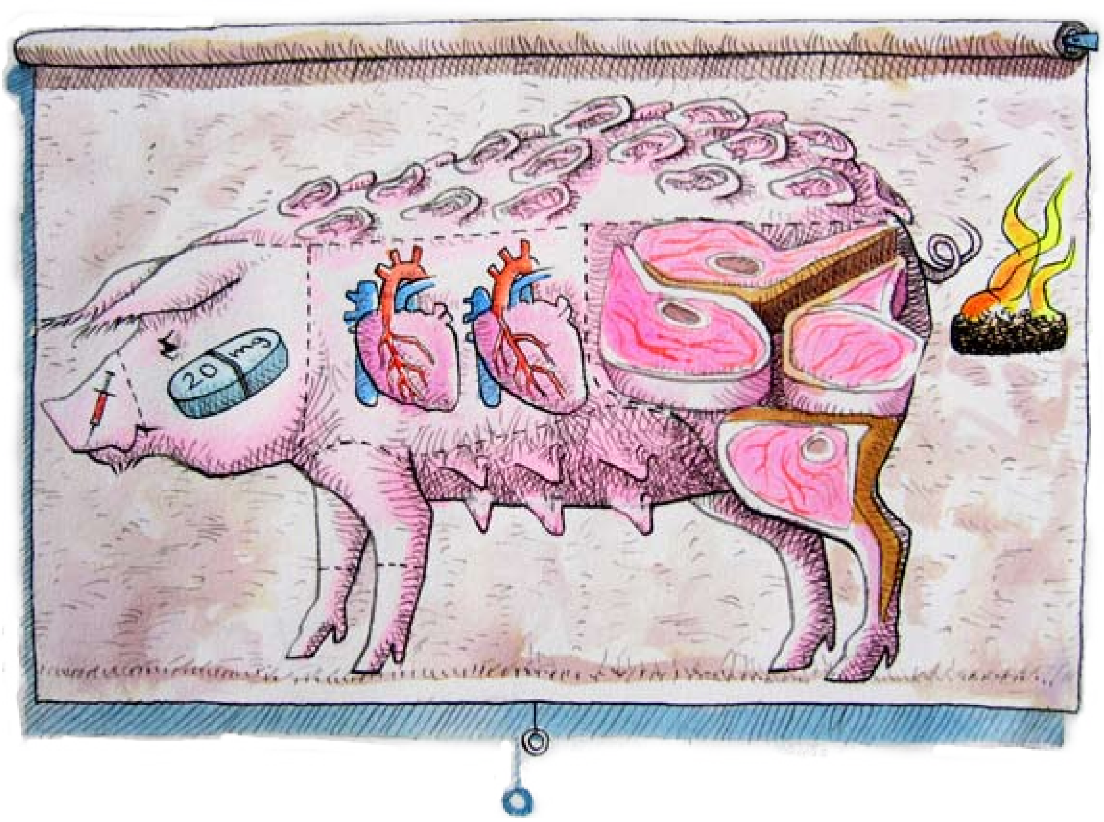
Soon, a few animals in a laboratory will be more valuable then all the livestock in all the coops, pens, and stockyards of the world. Think genetically engineered pigs incubating human hearts.[34] In fact, flocks of sheep with partially human hearts, livers, and brains are already a reality on a farm operated by the University of Nevada just miles outside Reno.[35]

Ancient alchemists dreamed of transmuting base metals into gold, discovering a universal cure for disease, and indefinitely prolonging life. Biotechnologists have inherited this dream, promising to convert soil and sunlight into the building blocks of human life. Disturbingly, our food has become a casualty of this promise. Seventy percent of the groceries on US supermarket shelves now contain GE ingredients[36] not because GE seeds are higher yielding or bear more nutritious crops then their conventional counterparts (under many growing conditions GE crops actually exhibit yield drag and are less nutritious).[37] Our food contains GE ingredients because single-trait genetic manipulations of corn and soybean plants* are the foundations from which more significant interventions in human genetics are being launched.

Propping up the Biotech Market

Food has become a casualty of biotechnology's promise because the agricultural sector offers pharmaceutical conglomerates unique opportunities to pursue the development and monopolization of proprietary biotechnology platforms while reducing their financial risks. The enormous public resources invested in agriculture have benefited these companies by promoting the sale of GE seeds over and above their actual value and by allowing them to multiply their research efforts at minimal cost through collaborations with public institutions.

* I am specifically referring to herbicide-tolerant and insect-resistant GE seeds. Together these two traits constitute nearly the entire market for GE seeds.



Over the course of the last century, farming has become increasingly capital intensive. Discrete elements of the agricultural production process have continually been displaced from farm fields, deconstructed in laboratories, reconstructed in manufacturing facilities, and reincorporated back into agriculture as purchased inputs.[38] Resources that were formerly sourced and supplied by the farm have been replaced by industrial equivalents. These changes in the structure and operation of American farms did not occur entirely of their own accord. Rather, they are the consequence of government policies that have promoted capital accumulation in the agricultural sector.

In 2000, nearly 50 percent of U.S. farms received payments for income or price support. These payments, comprising almost *one-half of net farm income,* reached a historic high of $20 billion that year.[39] Most of the payments farmers receive from the government are compensation for the difference between their high costs of production and the low market price. For example, in 2000 it cost farmers an average of $2.72 to grow a bushel of corn, while the market price was only $1.77.[40] Government payments largely covered the difference, helping to maintain farm solvency in the face of massive overproduction and rock bottom prices. As a result, farmers continue to push their yields, increasing both the absolute volume of inputs and the technological sophistication of those inputs, knowing that the expenses they incur will be covered by the generosity of Uncle Sam. That is, government support for commodity prices ultimately translates into government support for industrial inputs.

Industry sales are then further reinforced by tax policies: tax credits, accelerated depreciation, the special treatment of capital gains, all of which stimulate investment in agriculture by lowering the cost of capital.[41] These policies are then complemented by government-backed financial institutions such as the Farm Credit System and the Farmers Home Administration that lend to farmers at highly subsidized interest rates, thereby encouraging excessive capital investment for operating inputs.[42]

The bottom line is that industry has the government to thank for its sales. Government supported commodity prices, tax breaks on capital goods, and cheap credit translate into greater demand for manufactured inputs. These interventions have made it possible for agribusiness to sell products to farmers that actually increase their losses. (If it costs $2.72 to raise a bushel of corn for which you receive $1.77, the more you produce the more you lose). But so long as taxpayer funds can be used to foot the bill for these technologies and purchase the excess they generate at premium prices, farmers will continue to demand them.

Unfortunately, farmers are not the primary beneficiaries of federal largesse. For as Jeanne-Pierre Berlan calls to our attention, the “idea upon which modern agricultural policies were founded never intended to defend the family farm but to foster capital accumulation in the emerging agribusiness complex increasingly dominated by large corporations.”[43] Farm receipts as a percentage of total farm household income continue to fall and most farmers are forced to find off-farm work to make ends meet.[44] The fact of the matter is, the money we fork over as taxpayers eventually ends up in the pockets of agribusiness (strangely enough agribusiness now includes the pharmaceutical industry). It is with this in mind that we should evaluate the success of GE seeds, an invention whose adoption is largely attributable to government subsidies.

Priming the Biotech Pipeline

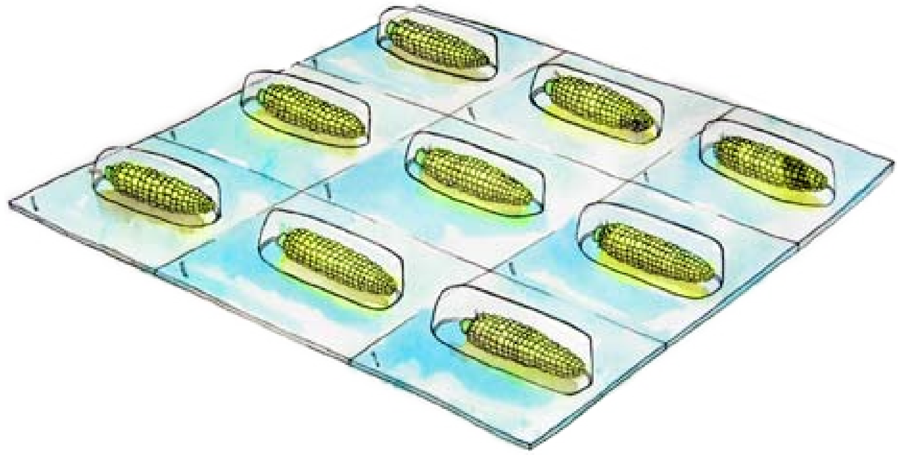
The government essentially promotes the sale of GE seeds; that is, so to speak, the demand side of the equation. On the supply side, universities and public research institutions enter into the analysis. The Harvard zoologist Richard Lewontin sums it up best when he notes:

> the costs of long-range research are socialized by changing the locus of the work from individual enterprises [i.e. pharmaceutical companies] to public institutions such as universities and national institutes. In this way, by tax subsidization, no individual firm need risk an investment and the total costs are spread over the entire tax base. [Then, when] such socialized research comes close to producing a marketable product, the final development stages are taken back into private hands to realize an exclusive property.[45]

Through their collaborations with public research institutions, the biotechnology industry has managed to reorient science, affecting what questions will be asked, which problems will be investigated, what solutions will be sought, and what conclusions will be drawn.[46] As research funding from federal and state sources continues to stagnate while universities seek to expand their research facilities,[47] they have progressively become more and more willing to entertain the designs of industry.

At State Agricultural Experiment Stations and Land-Grant Universities, the “lure of large sums of private money for biotechnology research have led to a change in disciplines,” as staff conducting agricultural biotechnology research have increased substantially at the expense of conventional breeding programs.[48] Through monetary enticements, private firms have managed to leverage their relatively minor financial contributions throughout the university or institute, thereby capturing within their orbit human and laboratory resources that are primarily sustained through public funding. A strategy reinforced by tax deductions: in California, the center of the biotechnology industry in the United States and home to the expansive and well-endowed University of California educational system,there is a 24 percent tax credit for business investments in university research.[49]

Federal legislation encouraging public-private partnerships and the patenting of university generated knowledge also serves to discipline public research to the pursuit of private profits. In 1974, prompted by Stanford University’s petition to patent the Cohen-Boyer recombinant DNA process, the National Institutes of Health decided to allow “universities to patent and license in the field of genetic engineering” greatly simplifying “the privatization of university research by removing any claims on behalf of the public regarding ownership of government-funded research.”[50] Most large research universities now have Offices of Technology Transfer (OTT) to facilitate cooperation between corporations and university researchers.[51] A development encouraged by the 1980 Bayh-Dole Act which officially made it legal for public universities to patent inventions, established frameworks to facilitate technology transfer from the public to the private sector, and made it possible for universities to go into business for themselves. Since then, universities have formed hundreds of startup companies “based on technology they developed and licensed”[52] – companies wherein faculty members frequently sit on the board serving as “advisers, recruiters of trained personnel, and information sources on current developments in academic science”.[53] A development which



offers these companies a foothold in the academy and assures that university research will be commercialized on industry's terms.

Normalizing Biotechnology

In addition to the financial advantages the agricultural sector offers the pharmaceutical conglomerates, there are ethical advantages to transforming the farm into biotechnology's frontier. The commercialization of genetically engineered corn, cotton, and soybeans introduces the world to biotechnology, yet these products insinuate themselves into our lives largely unnoticed because they are not primarily for human consumption[*] and are not animate in ways that normally invite anthropomorphism. Contrast society's general acceptance of GE corn, cotton, and soybeans with GE wheat: Monsanto's plans to introduce Roundup Ready wheat have been repeatedly delayed as farmers continue to express concern over consumer acceptance of a product that is largely for human consumption.[54] Consider also the reaction to GE animals: although the animal biotechnologies were "developed as early as the plant biotechnologies . . . they have taken longer to come to fruition because of greater scientific and regulatory challenges."[55] Transgenic pigs were developed as early as 1986 but as of this writing not a single biotech animal has been approved for commercial sale.[†] But with corn, cotton, and soybeans, the pharmaceutical industry found a secure space within the regulatory networks of agriculture that grants them carte blanche to genetically manipulate and commercialize complex organisms. This is a crucial next step, after the microbe and the single cell, in the quest for proprietary technology platforms that will be used to develop the next generation of health care products: plant and animal derived human proteins and human organs.

Thus, a clear pattern emerges: the taxes we pay have supported the failures of biotechnology, increasing the demand for GE seeds through government supports, subsidizing their supply through public research, and helping to create a regulatory framework in which these products might receive society's stamp of approval. All this has been done in the name of creating a more

* Only a tiny fraction of the millions of bushels of corn and soybeans grown in the United States are consumed by humans. Most is fed to livestock and much of the remainder is incorporated into industrial products. The corn and soybeans we do consume is usually a fractionated component of the whole food, i.e. high fructose corn syrup, lecithin, vegetable oil etc.

† Although GE animals have not been approved for commercial sale, due to negligence hundreds have ended up in the food supply. For one instance among many see: FDA. "FDA investigates improper disposal of bioengineered pigs". February 5, 2005. (Available at http://www.fda.gov/bbs/topics/ANSWERS/2003/ANS01197.html)

productive agriculture. These claims are a smoke screen for the development and monopolization of proprietary biotechnology platforms, which ultimately will be deployed toward more profitable ends than making more corn.*

Epilogue

In the 1940's, when grain yields per acre started to increase dramatically in the United States and continued to rise for decades, observers labeled the phenomenon the "Green Revolution." The increased productivity of the Green Revolution was based on the breeding efforts of scientists who scoured the world for plant traits that would benefit farmers – stiffer stalks, bulkier heads, resistance to disease, etc. These traits were discovered in farmers' fields but were not collectively present in any one single plant, so breeders took up the task of incorporating them into new seeds. These seeds promised higher yields, but something was lost along the way. Plants grown from these seeds were not as well adapted to their environment. They would fail to perform as expected unless supported by insecticides, herbicides, fertilizers, and irrigation – technologies which recreated the controlled environmental conditions of the laboratory.

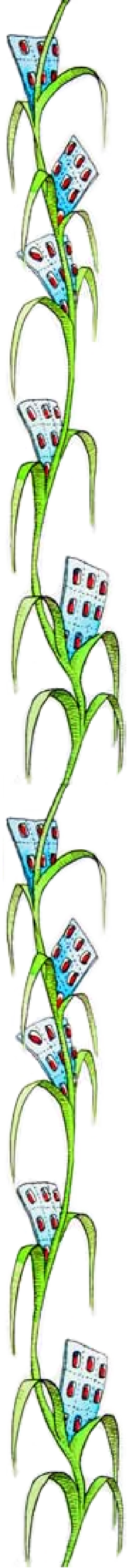
The Green Revolution sent a message to farmers: "If you want to increase your yields you must recreate our laboratory in your fields; you must replace your seeds with our seeds and institute our methods in place of your own."[56] More than anything else the Green Revolution was a revolution in the power of laboratories over the independence of farmers. This power emanates from the laboratory's ability to bind together actors situated beyond the laboratory into networks that employ and deploy the scientific facts and artifacts that they have generated.[57] When farmers adopted the technologies of the Green Revolution, they became part of this laboratory network. However, as dictated by the structure of the network, they did not share equally in its reward. Rather, they became dependent on technologies that they could not reproduce, that replaced their own resources, and that emanated from a remote center over which they had little control.

The so called "Gene Revolution," a term used to encompass the impact of biotechnology on agriculture, simply represents the latest frontier in the laboratory's struggle to subject farms and farming to the logic of capital. The space wherein the productivity of agriculture will be enhanced – the genome – is inaccessible to farmers even though it exists in their fields and sheds.

This is a dangerous development, for biotechnology is subject to tunnel vision. "Modern biology attempts to reduce nature to small, definable pieces, subject to human manipulation, and separated from broader questions of value. From this perspective, scientists control, measure, reduce and divide nature in order to generate knowledge."[58] But these methods alone are not conducive to a healthy and productive agriculture. Agricultural biotechnology is based on the premise that

> farming brings the farmer annually, over and over again, to the same series of problems, to each one of which there is always the same generalized solution . . .. But that is false . . .. neither the annual series of problems nor any of the problems individually is ever quite the same two years running."[59]

* At any one point in time the United States has more corn in storage than the 450 million people who make up the European Union consume, for all purposes, in an entire year. In total, the US has more corn sitting in silos than the next 10 countries combined. (Foreign Agricultural Service, USDA. "World Corn Production: Consumption and Stocks")



The inherent variability of farming from one place and time to another necessarily frustrates a one size fits all approach.[60] Yet with each passing year, the institutions we rely on for innovative agricultural solutions are more tightly yoked to a reductionist science whose frames of reference diminish the importance of holistic methods of inquiry. "As a consequence whole-plant- and whole-animal-level research (such as traditional breeding), systems-level research programs (such as agroecology, farming systems and social assessments), and indigenous knowledge . . . lack adequate support."[61]

To honestly address the problems facing agriculture today this trend must be reversed. We cannot stand inert while the agricultural research agenda is perverted by biotechnology's promise, while resources earmarked for agriculture are diverted and deployed to shore up the finances of the pharmaceutical industry. Public universities and government institutions are financially and morally obligated to serve the public interest. They are accountable to us and we must hold them to it. Collaborations between public institutions and private companies should be scrutinized to ensure that the public interest comes before private profits. Federal farm subsidies that encourage farmers to adopt capital-intensive production technologies that displace their own skills and local resources must be disassembled. Our current model of farm support that distorts the market for farm commodities, bankrupts farmers, fouls the environment, and offers the consumer pesticide-laced produce must be abandoned. A brighter future for farming is possible.

Acknowledgements: Many thanks to Anuradha Mittal, Melissa Moore, and Becky Tarbotton for their conceptual and editorial support and to Daniel Heimbinder whose ink and watercolor illustrations grace these pages.

Online Action

To learn more and get involved check out these online resources:

- www.eraction.org: Environmental Rights Action (ERA), the Nigerian chapter of Friends of the Earth International, is challenging the biotech push to promote "Medicine Rice" in Africa.

- www.ucsusa.org: The Union of Concerned Scientists, a science-based nonprofit working for a healthy environment, is campaigning to ban the outdoor use of food crops to produce pharmaceuticals and industrial chemicals.

- www.biosafety-info.net: The Biosafety Information Center, run by the Third World Network, provides up to date information regarding biosafety policies, laws, and practices at the international, regional, and national levels.

- www.centerforfoodsafety.org: The Center for Food safety works to protect human health and the environment by curbing the proliferation of harmful food production technologies.

- www.etcgroup.org: The ETC Group is a watchdog organization whose hard hitting reports on genetic engineering, nanotechnology, agriculture, and the environment unveil the machinations behind our meals.

- www.organicconsumers.org: The Organic Consumers Association campaigns in support of food safety, children's health, corporate accountability, fair trade, and environmental sustainability. Join their "Million Against Monsanto" campaign today.

- www.calgefree.org: Californians for GE Free Agriculture supports the rights of farmers and communities to evaluate and address the environmental, human health, and economic risks of genetic engineering in agriculture.

NOTES

1 Charles, Daniel. *Lords of the Harvest: Biotech, Big Money, and the Future of Food* Cambridge, MA: Perseus Publishing, 2001. p. xv.

2 Stone, Glen Davis. "Both Sides Now: Fallacies in the Genetic Modification Wars, Implications for Developing Countries, and Anthropological Perspectives." *Current Anthropology*. 43(2002): 611-630.

3 Monsanto. "Monsanto Company 2006 Annual Report." 2006. p. 74. (Available at http://www.monsanto.com/monsanto/content/investor/financial/reports/2006/2006AnnualReport.pdf)

4 Bergeron, Bryan P., and Paul Chan. *Biotech Industry: A Global, Economic, and Financing Overview*. Hoboken, NJ: J. Wiley, 2004. p. 175.

5 *The Economist*. "An Overdose of Bad News." March 17, 2005. (Available at http://www.economist.com/printedition/displayStory.cfm?Story_ID=3764524)

6 Charles, Daniel. *Lords of the Harvest: Biotech, Big Money, and the Future of Food*. p. 297.

7 Pollack, Andrew. "Pfizer, Hurt by Rival Generic Drugs, Will Lay Off 7,800." *The New York Times*. January 23, 2007.

8 Davoudi, Salamander. "Monsanto: giant of the 6.15 bn GM market." *Financial Times*. November 16, 2006.

9 Charles, Daniel. *Lords of the Harvest: Biotech, Big Money, and the Future of Food*. p. 295.

10 Ernst & Young. "Beyond Borders: The Global Biotechnology Report 2006." *Ernst & Young*. (Available at http://www.ey.com/global/Content.nsf/International/Media_-_Press_Release_-_Beyond_Borders_2006)

11 Agres, Ted. "US Biotech may Leap into the Black." *Drug Discovery and Development*. (Available at http://www.dddmag.com/ShowPR.aspx?PUBCODE=016&ACCT=1600000100&ISSUE=0407&RELTYPE=PR&ORIGRELTYPE=PNP&PRODCODE=00000000&PRODLETT=X)

12 Ernst & Young. "Beyond Borders: The Global Biotechnology Report 2006."

13 Jefferson, Richard A. "Transcending Transgenics: Are there 'Babies in the Bathwater' Or is that a Dorsal Fin?" *The Future of Food: Biotechnology Markets and Policies in an International Setting*. Ed. Philip G. Pardey. Washington, D.C.: International Food Policy Research: distributed by the Johns Hopkins University Press, 2001. p. 95.

14 Pollan, Michael. *The Omnivore's Dilemma: A Natural History of Four Meals*. New York: The Penguin Press, 2006. p. 94.

15 Watts, Michael, and David Goodman. "Agrarian Questions: Global Appetite, Local Metabolism: Nature, Culture, and Industry in *Fin-De-Siecle* Agro-Food Systems." *Globalising Food: Agrarian Questions and Global Restructuring*. Ed. David Goodman and Michael Watts. London ; New York: Routledge, 1997. p. 12.

16 Gardner, Bruce L. *American Agriculture in the Twentieth Century: How it Flourished and What it Cost*. Cambridge, MA: Harvard University Press, 2002. p. 141-142.

17 Magdoff, Fred, John Bellamy Foster, and Frederick H. Buttel. "An Overview." *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment.* Ed. Fred Magdoff, John Bellamy Foster, and Frederick H. Buttel. New York: Monthly Review Press, 2000. p. 11.

18 Goodman, David, John Wilkinson, and Bernardo Sorj. *From Farming to Biotechnology: A Theory of Agro-Industrial Development*. New York: Basil Blackwell, 1987. p. 138.

19 Scholz, Astrid J. "From Molecules to Medicines: The use of Genetic Resources in Pharmaceutical Research." *Engineering Trouble: Biotechnology and its Discontents*. Ed. Rachel Schurman and Dennis D. Kelso. Berkeley: University of California Press, 2003. p. 201.

20 Gaisford, James D. *The Economics of Biotechnology*. Cheltenham, UK ; Northampton, Mass.: Edward Elgar, 2001. p. 41.

21 Quoted in Boyd, William. "Wonderful Potencies: Deep Structure and the Problem of Monopoly in Agricultural Biotechnology." *Engineering Trouble: Biotechnology and its Discontents*. Ed. Rachel Schurman and Dennis D. Kelso. Berkeley, CA: University of California Press, 2003. p. 52.

22 Ibid., p. 44.

23 Brennan, Margaret F., Carl E. Pray and Ann Courtmanche. "Impact of Industry Concentration on Innovation in the U.S. Plant Biotech Industry." Transitions in Agbiotech: Economics of Strategy and Policy. Washington, D.C., June 24-25, 1999. p. 153.

24 Boyd, William. "Wonderful Potencies: Deep Structure and the Problem of Monopoly in Agricultural Biotechnology." p. 43.

25 Shreeve, Jamie. "The Other Stem-Cell Debate." *The New York Times Magazine*. April 10, 2005.

26 Gardner, John C., and Thomas L. Payne. "A Soybean Biotechnology Outlook." *AgBioForum* 6.1&2 (2003): 1-3. p. 1.

27 Boyd, William. "Wonderful Potencies: Deep Structure and the Problem of Monopoly in Agricultural Biotechnology." p. 43

28 Information in this paragraph was gathered from www.bio.org. The specific pages include "Advantages of Plants

to Produce Therapeutic Proteins" (Available at http://www.bio.org/healthcare/pharmaceutical/pmp/factsheet3.asp) and "A Brief Primer on ManufacturingTherapeutic Proteins" (Available at http://www.bio.org/healthcare/pharmaceutical/pmp/factsheet1.asp)

29 Ibid.

30 Information Systems for Biotechnology. 2005. "Field test releases in the U.S." (Available at http://www.isb.vt.edu/cfdocs/fieldtests1.cfm)

31 Elbehri, Aziz. 2005. "Biopharming and the food system: Examining the potential benefits and risks." *AgBioForum*. *8*(1), 18-25. (Available at http://www.agbioforum.org/v8n1/v8n1a03-elbehri.htm)

32 Van Brunt, Jennifer. "Molecular Farming's Factories." *Signals: the online magazine of biotechnology industry analysis*. February 19, 2002. (Available at http://www.signalsmag.com/signalsmag.3764d93a977219f888256b640069e224?OpenDocument)

33 Charles, Daniel. *Lords of the Harvest: Biotech, Big Money, and the Future of Food*. p. 193-194; Paraphrasing Robert Fraley.

34 For information concerning the race to develop genetically engineered animal organs for xenotransplanation to humans, see: *BBC*. "Pig Cloning Race Hots Up." January 3, 2002. (Available at http://news.bbc.co.uk/2/hi/science/nature/1740879.stm)

35 *Associated Press*. "Studies Mix Animal, Human organs." April 30, 2005. (Available at http://www.foxnews.com/story/0,2933,155123,00.html)

36 Wilson, William, Edward Janzen, and Bruce Dahl. "Issues in Development and Adoption of Genetically Modified Wheats." *AgBioForum* 6.3 (2003): 101-12. p. 104.

37 For information on yield drag in GE Soybeans see: Bohner, Horst. "What about Yield Drag on Roundup Ready Soybeans." News Releases. Ontario Ministry of Agriculture, Food, and Rural Affairs. March 2003. (Available at http://www.omafra.gov.on.ca/english/crops/field/news/croptalk/2003/ct_0303a9.htm) For information on the reduced nutrient content of GE soybeans see: Lappé, Marc A., et al. "Alterations in Clinically Important Phytoestrogens in Genetically Modified, Herbicide Tolerant Soybeans." Journal of Medicinal Food. 1.4 (1999). (Available at http://www.cetos.org/articles/abstract.html)

38 Goodman, David, et al. *From Farming to Biotechnology: A Theory of Agro-Industrial Development*. p. 2.

39 Government Accountability Office. *Farm Programs: Information on Recipients of Federal Payments*. Vol. GAO-01-606. Washinton, D.C.: GAO, 2001. p. 1.

40 Benbrook, Charles. "A Bill of Goods: Agricultural Policy, Trade and Technology Innovation since the Mid-1990's." Upper Midwest Organic Farming Conference. LaCrosse, Wisconsin, February26-28, p. 13-14. (Available at http://www.biotech-info.net/MOSES.pdf)

41 Atwood, Joseph A. "Implications of Tax Policy for Farm Structure." *Size, Structure, and the Changing Face of American Agriculture*. Ed. Arne Hallam. Boulder: Westview Press, 1993. p. 365.

42 Gardner, B. Delworth. *Plowing Ground in Washington: The Political Economy of U.S. Agriculture*. San Francisco, Calif.: Pacific Research Institute for Public Policy, 1995. p. 107.

43 "The Historical Roots of the Present Agricultural Crisis." *Towards a New Political Economy of Agriculture*. Ed. Friedland, William H. et al. Boulder, CO: Westview Press, 1991. p. 127-128.

44 Economic Research Service, USDA. "Farm Income and Costs: Farm Household Income." (Available at http://www.ers.usda.gov/Briefing/FarmIncome/forenew.htm)

45 Levins, Richard, and Richard C. Lewontin. *The Dialectical Biologist*. Cambridge, MA.: Harvard University Press, 1985. p. 201.

46 Noble, David F. *America by Design: Science, Technology, and the Rise of Corporate Capitalism*. 1st ed. New York: Knopf, 1977. p. 147.

47 Fuglie, Keith O. "Trends in Agricultural Research Expenditures in the United States." *Public-Private Collaboration in Agricultural Research: New Institutional Arrangements and Economic Implications*. Ed. Keith Owen Fuglie and David Schimmelpfennig. 1st ed. Ames, IA: Iowa State University Press, 2000. p. 12.

48 Busch, Lawrence, Jeffrey Burkhardt, and William B. Lacy. *Plants, Power, and Profit: Social, Economic, and Ethical Consequences of the New Biotechnologies*. Cambridge, MA, USA: B. Blackwell, 1991. p. 193.

49 Rausser, Gordon. "Public/Private Alliances." *AgBioForum* 2.1 (1999): 5-10. p. 9.

50 Kenney, Martin. "Biotechnology and the Creation of a New Economic Space." *Private Science: Biotechnology and the Rise of the Molecular Sciences*. Ed. Arnold Thackray. Philadelphia: University of Pennsylvania Press, 1998. p. 134.

51 Caswell, Margriet F., Keith Owen Fuglie, and Cassandra A. Klotz. *Agricultural Biotechnology : An Economic Perspective*. New York: Novinka Books, 2003. p. 14.

52 Lacy, William. “Generation and Commercialization of Knowledge: Trends, Implications, and Models for Public and Private Agricultural Research and Education.” *Knowledge Generation and Technical Change : Institutional Innovation in Agriculture.* Ed. Steven A. Wolf and David Zilberman. Boston: Kluwer Academic Publishers, 2001. p. 34.

53 Kenney, Martin. “Biotechnology and the Creation of a New Economic Space.” p. 137.

54 Pollack, Andrew. “Monsanto Shelves Plans for Modified Wheat.” *The New York Times*. May 11 2004.

55 Schurman, Rachel A. “Introduction: Biotechnology in the New Millennium: Technological Change, Institutional Change, and Political Struggle.” *Engineering Trouble: Biotechnology and its Discontents*. Ed. Rachel Schurman and Dennis D. Kelso. Berkeley, CA: University of California Press, 2003. p. 21.

56 I am reformulating Bruno Latour to make my point. The original reads as follows: “‘If you wish to solve your anthrax problem, come to my laboratory, because that’s where the forces are reversed. If you don’t (veterinarians and farmers) you will be eliminated’.” From: Latour, Bruno. “Give Me a Laboratory and I Will Raise the World.” *Science Observed: Perspectives on the Social Study of Science*. Ed. K. Knorr-Cetina and M. J. Mulkay. London: Sage Publications, 1983. p. 147.

57 Murdoch, Jonathan. “Inhuman/nonhuman/human: Actor-Network Theory and the Prospects for a Nondualistic and Symmetrical Perspective on Nature and Society.” *Environment and Planning D: Society and Space*. 15 (1997): 731-56. p. 737.

58 Lacy, William. “Generation and Commercialization of Knowledge: Trends, Implications, and Models for Public and Private Agricultural Research and Education.” p. 36.

59 Wendell Berry quoted in Scott, James C. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven, CN: Yale University Press, 1998. p. 296.

60 Lewontin, Richard C. “The Maturing of Capitalist Agriculture: Farmer as Proletarian.” *Hungry for Profit: The Agribusiness Threat to Farmers, Food, and the Environment*. Ed. Fred Magdoff, John Bellamy Foster, and Frederick H. Buttel. New York: Monthly Review Press, 2000. p. 93-106.

61 Lacy, William. “Generation and Commercialization of Knowledge: Trends, Implications, and Models for Public and Private Agricultural Research and Education.” p. 36.