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Monopoly in Agricultural Biotechnology**

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Engineering Trouble: Genetic Engineering and Its Discontents, (Kelso and
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**WONDERFUL POTENCIES?
DEEP STRUCTURE AND THE PROBLEM OF MONOPOLY
IN AGRICULTURAL BIOTECHNOLOGY**

William Boyd

The heredity values of specially bred strains of plants and animals are as real as the seemingly more concrete values of land or goods. Potent economic values run through generation after generation as persistently and as irresistibly as the river runs from its many springs to the sea. Unseen carriers of heredity determine whether the product shall be large or small, of high or low quality, lovely or homely. Their value to the nation is far above that of gold. Gladly we pay high prices for new “blood” in plants or animals because through the sure and potent agency of heredity the enhanced values continue during succeeding years. Heredity is a force more subtle and more marvelous than electricity. Once generated it needs no additional force to sustain it. Once new breeding values are created they continue as permanent economic forces.

-*Heredity: Creative Energy*, The American Breeders Magazine I, No. 2, 1910.

In their opening editorial for the spring 1910 issue of the *American Breeders Magazine*, Willet Hays and his staff offered a grand vision of heredity as a productive force. In their view, and presumably in the view of most members of the American Breeders Association, the new “science” of breeding and genetic improvement promised a sort of second industrial revolution for agriculture – a qualitative advance beyond ongoing efforts to improve productivity through mechanization and the application of fertilizers and other exogenous inputs. As breeding values were transformed into property rights, they would become key vehicles for capital accumulation and, more broadly, for the industrialization of agricultural systems. At the beginning of the twenty-first century, more than one hundred years after the rediscovery of Mendel’s work on

inheritance, the application of the new biotechnologies promises to push this logic of intensification further than Hays and his colleagues likely ever imagined.

A professor of agriculture at the University of Minnesota and later undersecretary of agriculture, Hays was the founding secretary and guiding force behind the American Breeders Association (ABA). Founded in 1903 and composed of commercial breeders, scientists from agricultural colleges and experiment stations, USDA researchers, and other people interested in inheritance and breeding, the ABA proved to be an early force in the assimilation of Mendel's work into the practice of breeding (Kimmelman 1983; Rosenberg, 1997: 211-224; Paul and Kimmelman 1988). ABA members were among the first to appreciate the predictive value of Mendelian ratios and set to work on applying the "fundamental laws of breeding" to agricultural improvement. Here was an early illustration of the marriage of science and industry in an effort to press biology into the service of commercial gain. In the vision of Willet Hays, the ABA would bring together scientists and practical breeders "in a grand cooperative effort to improve those great staple crops and magnificent species of animals." Only on the basis of such cooperation between "the breeders and the students of heredity", Hays argued, could the "wonderful potencies of heredity be harnessed and placed under the control and direction of man as are the great physical forces of nature" (Hays 1905: 9-10).¹

One does not have to look far in today's politically-charged debate over agricultural biotechnology to find boosterism that rivals that of Hays and the ABA. Americans and American business leaders have always had a remarkable enthusiasm for new technologies (Hughes 1989). Yet, where Hays spoke directly of harnessing heredity for economic and commercial gain, today's advocates tend to invoke a vision of a

healthier and more environmentally friendly agriculture – often posed against a Malthusian backdrop of world famine. Lurking beneath the surface, of course, are the priorities of national competitiveness in strategic “high-tech” sectors and the power of large multinational corporations seeking to capitalize on the wave of innovations and proprietary technologies associated with recombinant DNA techniques (Wright 1998). In the process, the structure and practice of agriculture and agro-food systems are undergoing a substantial reorganization – the limits of which are not entirely clear.

The main stumbling block today, it seems, is not so much the science but the politics. Indeed, the politics surrounding agricultural biotechnology seem to be more potent than the “breeding values” themselves. As the public outcry against genetically modified foods spreads from Europe to the US and beyond, several of the first-movers in the field, most notably Monsanto, appear to be in trouble – their strategy for creating an integrated life-sciences complex very much on hold (Niiler 2000; Eichenwald et al 2001). Some have even suggested that agricultural biotechnology is in danger of going the way of nuclear power in the United States – a pariah technology that never lived up to initial expectations (Loewenberg 1999). While this may be a rather extreme reaction, there clearly are a number of serious potential legal and regulatory issues that could severely dampen the enthusiasm of investors and consumers – without whom, of course, the technology does not have much of a chance.²

Despite these lingering concerns and uncertainties, however, the commercial penetration of agricultural biotechnology in the United States and several other major crop producing regions has been nothing short of astonishing. Since their introduction in 1996, the global area of the four principle transgenic crops (soybeans, canola, cotton, and

corn) has increased to roughly 40 million hectares (100 million acres), comprising approximately 30% of global soybean acreage; 14% of global canola acreage; 10% of global cotton acreage; and 8% of global corn acreage (1999 figures). This represented an increase of 44% over 1998 acreages (James 2000).³ Consequently, the value of the global market for transgenic seeds has grown from a paltry \$150 million in 1996 to an estimated \$3 billion in 1999 (James 2000).

Not surprisingly, the US has emerged as the leader in the adoption of agricultural biotechnology. By 1999, some 72% of the global area of transgenic crops was concentrated in the US, but acreages continue to expand in a number of other grain and oil-seed producing regions around the world. In 1999, roughly half of the US soybean crop, half of the US cotton crop, and one-third of the US corn crop were planted with transgenic varieties (James 2000). Despite considerable commentary in the press and elsewhere that the adoption of these transgenic crops would level off because of the public concerns regarding genetically-modified food products, US farmers continue to embrace the technology. According to recently released USDA figures, for example, the total proportion of US soybean acreage planted with transgenic varieties increased from 54% in 2000 to 63% in 2001 (Brasher 2001).

As of May 1999, US regulators had approved some fifty-three different transgenic products for thirteen different crops, the vast majority are directed toward herbicide tolerance and insect resistance (USDA-ERS 2001: 18). This first generation of “input-oriented” traits has focused exclusively on crop protection, with farmers being the primary target. The next generation of so-called “output-oriented” traits, which are just reaching commercialization, are focused on engineering qualities into crops that will

produce enhanced food and feed products, i.e. feed grains with enhanced amino acids, high oil corn, beta carotene enhanced rice, field crops that produce vaccines and other specialty chemicals, etc. (USDA-ERS 2001: 19). These products are focused more on consumers and other end users rather than farmers and do not necessarily carry with them the same sorts of health and environmental concerns that the current generation of crop protection traits do.

What has perhaps been most remarkable (yet least noticed) about the commercial success of agricultural biotechnology, however, is the massive industrial consolidation that has accompanied the spread of these technologies. As Table 1 below indicates, the top three global seed companies are now all chemical companies – each of which moved aggressively into the life sciences field during the 1990s. With its \$7.7 billion purchase of Pioneer Hi-Bred in 1999, DuPont became the largest seed company in the world. Likewise Monsanto spent close to \$8 billion acquiring seed companies and other biotechnology firms during the second half of the 1990s. Novartis and Dow made similar moves. All told, between 1996 and 1999, there were roughly \$15 billion worth of mergers in the global seed industry (a remarkable figure given that total value of the global seed market is only \$25 billion), driven almost entirely by the desire to acquire high quality germplasm in order to use it as a vehicle for proprietary traits.⁴ Today, two companies, DuPont and Monsanto, control more than 70% of the market for US corn seed (see Table 1). Through its acquisition of major seed companies and its aggressive licensing program, Monsanto now holds the number two market position in the US corn seed market, the number one position in the Brazilian, Mexican, and Argentine corn seed markets, the number one position in the US soybean seed market, and the number one

position in the European wheat market (Monsanto 2000: 66-67). Viewed in the aggregate, these developments represent a profound restructuring in the ownership and control over the germplasm resources for the major commercial crops, posing substantial implications for the structure, organization, and practice of agro-food systems.

[TABLE 1 ABOUT HERE]

As for the market for agricultural biotechnology, Monsanto has clearly established itself as the early leader – commanding a market share of more than 80%. Out of the total global acreage of 100 million acres of transgenic crops, Monsanto’s agricultural biotechnology products were planted on some 86 million acres in 1999 (Monsanto 2000: 65). Much of this success stems from the company’s Roundup Ready soybeans, which have been genetically engineered to tolerate Monsanto’s glyphosate-based herbicide Roundup (Monsanto 2000: 65).⁵

Following Monsanto, leading firms have pursued a general strategy of building a vertically integrated structure that links research and development of specific biotechnology products (traits) with seed delivery systems (seed companies) in order to deliver farmers a package of value-added inputs (seeds and chemicals). The diagram in the appendix at the end of this essay presents a schematic representation of the structure

TABLE 1: SEED INDUSTRY CONSOLIDATION

Top 10 Global Seed Companies, 2000

*Source: Rural Advancement Fund
International*

US Corn Seed Market Shares, 2000

*Source: JP Morgan, Chemical Mkt
Reporter*

Company	1999 Seed Sales (million US \$)	Company	Market Share
1. DuPont/Pioneer (USA)	\$1,850	1. DuPont/Pioneer	42%
2. Monsanto (USA)	\$1,700	2. Monsanto	30%
3. Syngenta (Novartis & Astra Zeneca) (Swiss/UK)	\$947	3. Syngenta	9%
4. Groupe Limagrain (France)	\$700	4. Dow	4%
5. Grupo Pulsar/Seminis (Mex.)	\$531	5. Cargill	3%
6. Advanta (UK/Netherlands)	\$416	6. Other	12%
7. Sakata (Japan)	\$396		
8. KWS AG (Germany)	\$355		
9. Dow (USA)	\$350		
10. Delta Pine & Land (USA)	\$301		

of the agricultural biotechnology complex circa 1999. As suggested, this process of vertical and horizontal integration has resulted in consolidation of control over the basic transformation technologies used in the genetic modification of crops; control over proprietary traits; and control over the elite germplasm resources for many of the world's most important commercial crops. Patent rights, and the strategies these firms have deployed to capture the value associated with these patents, have been a driving force in this restructuring. Understanding how and why these changes have occurred is the task of this essay.

Through an examination of the historical development of the agricultural biotechnology complex and, in particular, the strategies employed by major firms in their attempt to build an agro-industrial complex centered on biotechnology and the life sciences, this essay explores the construction of a new industrial order that is dramatically reshaping the economic landscape.⁶ The observation that motivates the essay is that there is a deep structure to the agricultural biotechnology complex that derives from the particular ways in which science, law, and business have come together in an effort to industrialize *agricultural* systems. Over the last several decades, and especially over the last ten years, key actors have been engaged in constructing a new industrial order that, if successful, promises to reshape large segments of the global agro-food system. Understanding how this industrial order came to be and the implications it raises for law and policy are the primary objectives of this essay.

The essay is divided into four sections. The first examines the transformation of agricultural breeding efforts under the impact of modern genetics and molecular biology. The highly reductionist view of life that came to dominate breeding and genetic

improvement efforts during the post-WWII period was accompanied by an accelerated shift in the locus of innovation from the public land-grant complex to private biotechnology companies, large “life-sciences” multinationals, and more recently, small boutique genomics firms. Underlying this shift, of course, have been certain key legal developments that have allowed both for the transformation of “novel” life forms and genetic sequences into new forms of property and for the reconfiguration of relationships between public and private science. The new incentive structures that have emerged –for universities and university scientists wanting to capitalize on their own research as well as for large companies wanting to establish first-mover advantages in the sector – have facilitated a race to develop and/or acquire a portfolio of intellectual property rights as the basic platform for the agricultural biotechnology enterprise. These legal and institutional issues will be the focus of the second section of the paper. The third section then looks at the organizational strategy employed by Monsanto and other first-movers to create a vertically-integrated structure capable of capturing the economic value associated with these new forms of property – specifically through the acquisition of key germplasm resources, seed delivery systems, and horizontal and vertical licensing arrangements. Finally, the concluding section addresses some of the challenges -- legal, political, and economic -- associated with the emerging architecture of the agricultural biotechnology complex and suggests some of the reasons why the question of regulation and governance is so challenging.

The basic argument of the essay is relatively straightforward: There are powerful monopolistic tendencies embedded within the deep structure of the agricultural biotechnology enterprise. These tendencies are distinctive to the sector and they derive in

large part from the synergies that have developed between the increased precision and calculability in the science of genetics and the techniques of genetic manipulation, a stronger intellectual property regime for life forms, and the biological and social facts of agriculture. In short, as the notion of “life as code” has emerged as a governing paradigm within molecular biology and as the technology of recombinant DNA has become a practical reality, the specificity and frequency with which proprietary claims can be made over “novel” life forms have grown enormously. The emergence of a stronger intellectual property regime for such “novel” life forms since the early 1980s has also made the acquisition of such property rights far more valuable, adding to the incentives to consolidate an intellectual property platform as the foundation for the agricultural biotechnology enterprise. Creating such a foundation has obviously entailed substantial capital investment, adding to the imperative of developing an organizational structure capable of delivering value. Because proprietary traits are useless without access to existing germplasm and seed delivery systems for key commercial crops and because farmers (in some capacity) are necessary to provide the critical “grow-out” stage in order for firms to capture the value associated with their proprietary technologies, vertical integration has emerged as a key institutional vehicle for capturing value. Thus, leading firms, particularly Monsanto and DuPont, have acquired major seed companies and developed a system of contract farming tailored to the new biotech crops. In the long-run, the hope is to integrate further downstream into the food processing sector – linking the input and output segments of the agro-food chain into a coordinated industrial system. The overall result of these efforts, accomplished in less than a decade, is a global oligopoly of five firms that now controls huge segments of the global agro-food complex.

And it is this development – as much as labeling and biosafety – that begs attention from regulators, academics, and the public itself.

Breeding and Biotechnology: Life as Code

Heredity is described today in terms of information, messages and code. The reproduction of an organism has become that of its constituent molecules. This is not because each chemical species has the ability to produce copies of itself, but because the structure of the macromolecules is determined down to the last detail by sequences of the four chemical radicals contained in the genetic heritage. What are transmitted from generation to generation are the ‘instructions’ specifying the molecular structures: the architectural plans of the future organism.

-François Jacob, 1973, *The Logic of Life: A History of Heredity*, Betty E. Spillman trans., Princeton: Princeton University Press, 1.

The metaphor of life as code has become second nature in the era of modern biotechnology. Drawing heavily on ideas from information theory and cybernetics, this “informationist” solution to some of the basic problems of molecular biology has come to provide much of the foundation for efforts to “improve” biological systems by intervening directly in the genetic program itself. Codes, as Lily Kay reminds us, can be cracked, programmed, and re-programmed. The idea that the basic architecture of the organism is contained within its genetic code carries with it all sorts of interventionist possibilities (Kay 1998, 2000; Keller 1993).

The intellectual and institutional histories of molecular biology and, specifically, the story of how the structure and function of DNA was identified and elaborated are familiar enough (Allen 1978: ch. 7; Mayr 1982: chs. 18-19; Kay 1993, Morange 1998). As the “heroic” age of theoretical advance and synthesis gave way to what Kuhn (1969) called “normal” academic science focused on refining and extending the key elements of

the Watson-Crick model of the structure of DNA, the possibilities of moving to more applied pursuits began to open up – both in medicine and agriculture. The basic insight that all organisms use the same rules for turning nucleotide sequences into amino acid sequences using three letter nucleotide “codons” created the opportunity for the development of modern biotechnology. By the early 1970s, the demonstration by Stanley Cohen and Robert Boyer that pieces of DNA could be taken from one organism and inserted into another in a manner that would lead to coding for particular proteins ushered in the recombinant era. For agricultural scientists and breeders, this provided the technical means for transcending the species barrier and moving genes that coded for desirable traits (assuming they could be found and isolated) between different organisms. The view of geneticists and molecular biologists as code breakers was conjoined with that of breeders as genetic engineers – architects capable of reconfiguring, rather than simply discovering and cultivating, genetic information in a manner that would generate new “breeding values”.

When combined with the possibility of protecting these efforts through new forms of property (an issue taken up in the next part) and the presence of an infrastructure of financial and legal services, the commercialization of biotechnology seemed to be a foregone conclusion. Out of this institutional matrix emerged the new “scientist-entrepreneur” with one foot in the world of university research and the other in the world of high-tech start-ups. Following in the footsteps of the larger biomedical start-ups, notably Genentech, Amgen, and Chiron, agricultural biotechnology start-ups such as Agracetus, Calgene, and Mycogen promised to create new crops and techniques that represented a qualitative advance beyond previous agricultural improvement efforts

(Kenney 1986, 1998). In addition to these start-up efforts, Monsanto and several other large chemical firms began to move into the area during the early 1980s -- focusing on acquiring and developing the necessary science and the key enabling technologies (along with the associated intellectual property rights) in order to build an innovation pipeline.⁷

Progress in the lab came quickly. In 1983, California-based Calgene announced that it had discovered a mutant bacteria gene conferring resistance to the broad-spectrum herbicide known as glyphosate. Specifically, the gene coded for a mutant form of an enzyme that had immunity to glyphosate. If it could be successfully inserted and expressed in crop plants, Calgene hypothesized, the gene might enable farmers to solve all their weed problems in a single herbicide application – a prospect that proved particularly interesting to Monsanto, given that glyphosate was the active ingredient in its best selling herbicide Roundup (Chemical Week 1983: 28). Spurred by this development, Monsanto unveiled a \$150 million biotechnology research center the following year and announced that it had successfully expressed a mammalian protein in a plant. President and CEO Richard J. Mahoney also noted that the company would shift a third of its research efforts away from commodity petrochemicals toward agriculture, animal nutrition, and health care – hoping to commercialize its first biotech product by the end of the decade (Biotechnology Newswatch 1984: 1). Other major chemical firms followed suit by establishing their own research initiatives – joining the race to develop and commercialize new biotech products (Trehitt and Bluestone 1985: 34).⁸ In addition to beefing up in-house research efforts, these companies also began developing research agreements and alliances with smaller biotech firms (Trehitt and Bluestone 1985: 34).

The lure of biotechnology for these companies was not hard to understand. Up until the 1950s, researchers could come up with one commercially useful pesticide compound for every 2,000 screened. By the 1980s, largely because of increased resistance, researchers were screening 20,000 or more compounds to come up with a single product. Developing a new crop protection product and taking it to market took an average of seven years and cost roughly \$30 million. The new techniques of genetic engineering held out the promise of accelerated and more precise development of new products – speeding and expanding scientists’ understanding of why certain chemicals affect plants in certain ways (Trehitt and Bluestone 1985: 34). As one biotechnology researcher put it, “[i]n the past we played roulette. We now have control over where the ball lands.” (Quoted in Rotman 1993: 33). Given the maturity of the agro-chemical market, moreover, most of these firms were eager to find new ways to generate revenue growth. Agricultural biotechnology, in short, held out the potential for accelerated product cycles and new value-added products.

By 1985, initial investments began to bear fruit. In January, biotechnology start-up Plant Genetic Systems announced that it had succeeded in inserting a *Bacillus thuringiensis* (Bt) gene⁹ into a tobacco plant – laying the groundwork for the development and commercialization of insect resistant technology in the years ahead. The following month, Calgene announced that it had successfully expressed its glyphosate resistant gene in tobacco plants and had initiated glyphosate tolerance projects in a wide range of other crops (Trehitt and Bluestone 1985: 34). Not to be outdone, Monsanto followed several months later with an announcement that it had genetically engineered petunia, tobacco, and tomato plants to successfully tolerate commercial

sprayings of its own glyphosate-based Roundup herbicide. In a sign of the impending competition in the sector, Monsanto also noted that Calgene's efforts to engineer glyphosate resistance were only effective at dilute concentrations and thus not commercially viable (Biotechnology Newswatch 1985: 3). At the same time, various firms also accelerated their efforts to develop new and more effective transformation techniques. In addition to discovering and patenting useful traits and new transgenic plant varieties, control over key transformation technologies held out the possibility of substantial competitive advantage.¹⁰ The gene wars had begun.¹¹

As efforts in the lab progressed, attention quickly shifted to field testing and regulatory approval. By the 1989 planting season, researchers were conducting some fifty-nine different field tests for genetically engineered plants – up from fewer than ten in 1988. If the regulatory process went smoothly, researchers hoped to commercialize the first transgenic crops by the early 1990s (Biotechnology Newswatch 1989: 5). In 1992, the White House released guidelines promoting genetically-altered foods – lifting a major cloud of uncertainty over the industry and giving it a green light as far as regulatory hurdles were concerned (Biotechnology Newswatch 1992a: 1).¹² Four years later, the first transgenic crops entered commercial production. Based on the technologies of herbicide tolerance and insect resistance developed during the previous decade, these new crops promised to revolutionize American agriculture. After close to fifteen years of research and development, leading firms had successfully translated the notion of life as code and the interventionist possibilities associated with recombinant DNA techniques into commercial reality.

Notwithstanding their substantial investments in research and development, however, these emerging life sciences firms proved unable to keep up with the rapid pace of innovation in the biotechnology sector. During the mid-1990s, just as the first transgenic crops were being commercialized, the growing emphasis on genomics¹³ and bioinformatics¹⁴ forced Monsanto and other firms to develop strategic alliances with some of the leading companies in the genomics area and invest heavily in their own genomics efforts (Ratner 1998: 810-11). By the end of the decade, genomics had become the driving force of innovation in the industry – reshaping research agendas and stimulating even more intense competition to acquire key intellectual property rights.

Pioneer Hi-Bred kicked off the genomics race in 1996 through an alliance with Human Genome Sciences to sequence corn genes. As the largest seed company in the world, Pioneer was clearly “in the market” for genes and realized that sequencing offered a potential shortcut to the patent office (Fairley 1998f: 18).¹⁵ Shortly after Pioneer’s initial foray into genomics, Monsanto announced its own research collaboration with another leading genomics firm, Palo Alto based Incyte Pharmaceuticals (Rotman 1997a: 14).¹⁶ The following year, in 1997, Monsanto entered into a five-year \$218 million dollar collaboration with genomics powerhouse, Millennium Pharmaceuticals of Cambridge, Mass. Under the terms of that deal, Monsanto received exclusive access to Millennium’s genomics technologies for all crop plants. At the same time, Monsanto also formed a wholly-owned genomics subsidiary – Cereon – for the purposes of collaborating with Millennium in gene discovery (Nature Biotechnology 1997). Such deals were intended to significantly increase Monsanto’s expertise and capabilities in mapping and sequencing genes – complementing its efforts to put a seed delivery organization in place

and develop techniques for genetic modification. In the words of Steven Holtzman, Millennium's chief business officer, "Monsanto has all the tools necessary to deliver high-value genes in genetically engineered crops. Now it needs the genes." (Quoted in Rotman 1997a: 14).¹⁷

Playing catch-up with Monsanto, DuPont and Novartis announced their own independent genomics investments in 1998 – betting that genomics capabilities would be critical in the race to identify (and patent) novel traits for crop-protection and crop-enhancement. Witness the words of DuPont manager Forrest Chumley, "Very shortly all the genes that matter are going to be cloned [isolated for patent purposes]. There's a real race to get there first." (Quoted in Fairley 1998b: 9). In July 1998 Novartis initiated a \$600 million, ten-year plant genomics initiative, the centerpiece of which would be a \$250 million genomics center, the Novartis Agricultural Discovery Institute, in San Diego, CA. In addition, Novartis developed strategic alliances with other genomics firms and universities, such as the University of California-Berkeley, giving the company right of first refusal on any patents produced through the initiative. Initial plans were to fund some 180 scientists working in 50 labs with a focus on generating databases on the relationships between genes, proteins, and specific traits (Welch 1998: 23; Fairley 1998b: 9).

By the late 1990s, with improved automation and increased capacity for sequencing and high-throughput screening, genomics took center stage as the locus of innovation in agricultural biotechnology – raising the stakes in plant biotech research. According to Monsanto, these new technologies drove the total cost of sequencing a gene from approximately \$150 million in 1974 down to \$150 by 1998 (Enriquez 2000: 7). By

developing databases of genes and gene markers for major crops, the goal was to gain a deeper understanding of the entire genetic code of valuable crops in the hope of identifying valuable new traits and breeding strategies and, of course, locking up as much intellectual property as quickly as possible.¹⁸

The promise of genomics lay in the possibility of significant time compression in breeding efforts and the potential of acquiring new patent claims over the next generation of genetically modified traits (Holmberg 2000: 1; Reichman et al 1999: 12).¹⁹ By February 2001, initial investments appeared to be bearing fruit when Syngenta (formally Novartis) announced that its genomics research center had completed a map of the rice genome (the first complete genome sequence for a commercial plant) – beating out a number of rivals including Monsanto and the publicly financed International Rice Genome Sequencing Project. Although Syngenta promised to release the information without cost to research institutes that serve third world countries as well as to academic scientists, the fact that a private entity produced the first genome map of such a commercially important crop reinforced fears that the genetic resources so central to world agriculture were vulnerable to proprietary control (Smith 2001: 1; Associated Press Newswires 2000; Jacobs 2000).

In essence, the advent of genomics marks a further step in the ongoing transformation of biology into an information science. While it is not entirely clear what the “product” is and where the ultimate payoff will be with genomics, it is clear that the locus of innovation in the agricultural biotechnology industry has shifted decisively from attention to single gene traits and gene transfer to genomics.²⁰ In some respects, the reductionism that has distinguished genetics and molecular biology during the post-

WWII period has given way to a more holistic approach to mapping the entire genomes of particular organisms. The challenge, of course, lies not in determining the actual sequence of an organism's genome, but rather in interpreting it. The sequences of model organisms -- yeast, the nematode *c elegans*, and the fruit fly *drosophila* – are intended to provide a 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 foundation for uncovering the basic processes of gene function and protein synthesis common to all organisms (Lander and Weinberg 2000). For agriculture, genomics promises not only an acceleration of ongoing breeding efforts but a greater precision in the ability to understand and control critical metabolic pathways – a new stage in the effort to harness the power of heredity (Gura 2000).

This ongoing trend toward ever greater precision and calculability in the understanding of heredity and the transformation of that understanding into new “breeding values” derives in large part from the “informationist” approach to biology – from the notion of life as code. In the process, new possibilities for intervention and manipulation have opened up, allowing leading firms to develop a truly awesome array of capabilities.²¹ At the same time, this trend has been accompanied by an ongoing and deepening tendency of proprietary control. Simply put, as the understanding of heredity has moved to the molecular level, the precision with which one can represent new “breeding values” has increased considerably – allowing for more specific legal claims and an improved ability to enforce such claims – all of which works to further encourage privatization. In the context of the broad and hospitable intellectual property system that

has emerged in the United States, the new science of biotechnology has thus created a wealth of opportunities for new forms of property.

Patenting Life: The Legal Architecture of a New Economic Space

Here, by contrast, the patentee has produced a new bacterium with markedly different characteristics from any found in nature and one having the potential for significant utility. His discovery is not nature's handiwork, but his own; accordingly it is patentable subject matter.

-*Diamond v Chakrabarty*, 447 U.S. 303, 310 (1980).

The ability of genes derived from totally different biological classes to replicate and be expressed in a particular microorganism permits the attainment of interspecies genetic recombination. Thus, it becomes practical to introduce into a particular microorganism, genes specifying such metabolic or synthetic functions as nitrogen fixation, photosynthesis, antibiotic production, hormone synthesis, protein synthesis, e.g. enzymes or antibodies, or the like—functions which are indigenous to other classes of organisms—by linking the foreign genes to a particular plasmid or viral replication.

-*Process for Producing Biologically Functional Molecular Chimeras*, (First Cohen-Boyer Patent) United States Patent 4,237,224, December 2, 1980.

It is the policy and objective of the Congress to use the patent system to promote the utilization of inventions arising from federally supported research or development; [and]. . . to promote collaboration between commercial concerns and nonprofit organizations, including universities.

-BAYH-DOLE ACT, P.L. 96-517, December 12, 1980, codified at 35 U.S.C.A. §200.

Three major legal developments in 1980 – one judicial, one administrative, and one legislative – established much of the basic legal architecture that has structured the U.S. biotechnology industry. In June of 1980 the Supreme Court handed down its famous *Chakrabarty* decision, overturning the Patent and Trademark Office's denial of a utility patent for a newly engineered bacterium capable of metabolizing oil (*Diamond v Chakrabarty*, 447 U.S. 303 (1980)). Six months later on December 2, 1980, the U.S.

Patent and Trademark office issued the first Cohen-Boyer patent (the process patent), which gave Stanford and the University of California patent rights to the basic technique of genetic engineering (US Patent No. 4,237,224).²² And ten days after that Congress passed the Bayh-Dole Act of 1980, allowing for the commercialization of federally-sponsored research and ushering in a new era of university-industry collaboration and technology transfer between the public and private sectors (35 U.S.C.A. §200). Together these three developments created a new economic space within which the biotechnology industry could flourish.

The Chakrabarty Regime

Chakrabarty stood for the principle that human-engineered life forms were patentable subject matter under §101 of the Patent Act.²³ The case involved a patent claim by General Electric scientist Ananda Chakrabarty on a microbe that he had developed for the purpose of degrading crude oil. In his patent application, Chakrabarty claimed the process of making the organism, a method for dispersing it, and the organism itself. The US Patent & Trademark Office (PTO) accepted the first two claims, but denied the third on the grounds that the microorganism itself was a “product of nature” and thus not patentable subject matter.²⁴ By a 5-4 decision, the Supreme Court rejected the arguments of the Patent Office, paving the way for a new and stronger intellectual property regime governing living organisms and their constituent parts. As such, the decision was part of a more general trend in U.S. patent law that took shape during the early 1980s and resulted in stronger patent protections and extensions of patentability into new areas.²⁵

Writing for the majority, Chief Justice Burger affirmed the Court's precedents that "laws of nature, physical phenomena, and abstract ideas have been held not patentable (447 U.S. 303, 309)." In doing so, he distinguished the Chakrabarty facts from a 1948 case, *Funk Brothers Seed Co. v. Kalo Inoculant Co.* 333 U.S. 127 (1948), that had explicitly rejected patent eligibility for a class of cultured root-nodule bacteria useful in stimulating nitrogen fixation among plants. In that case Justice Douglas noted that "patents cannot issue for the discovery of the phenomena of nature. The qualities of these bacteria, like the heat of the sun, electricity, or the qualities of metals, are part of the storehouse of knowledge of all men. They are manifestations of laws of nature, free to all men and reserved exclusively to none (333 U.S. 127, 130)."

But the Chakrabarty case was different precisely because of the nature and scope of human intervention necessary to engineer the new bacterium. In contrast to the bacteria involved in the earlier *Funk Brothers* case, which represented "no more than the discovery of some of the handiwork of nature (333 U.S. 127, 131)," Chakrabarty's bacteria were not naturally occurring – begging the question of whether "living organisms," natural or not, should be eligible for patent protection. In interpreting the relevant statutory language and legislative history of the various Patent Acts, Burger stressed that Congress "plainly contemplated that the patent laws would be given wide scope (447 U.S. 303, 308-09)." Quoting from the Committee Reports accompanying the 1952 Patent Act, Burger emphasized that Congress intended patentable subject matter to "include anything under the sun that is made by man (447 U.S. 303, 309)." Thus, because Chakrabarty's new bacterium was "not nature's handiwork, but his own," it was

patentable subject matter. The distinction between living and non-living had no place in the patent law (447 U.S. 303, 310).

In a powerful dissent, Justice Brennan pointed out that Congress had previously addressed the issue of intellectual property protection for certain life forms through the Plant Patent Act of 1930 and the Plant Variety and Protection Act of 1970. These acts, he argued, “strongly evidence a congressional limitation that excludes bacteria from patentability (447 U.S. 303, 319).”²⁶ The fact that Congress found it necessary to enact specific legislation to extend patent-like protection to certain plant varieties demonstrated Congress’s intent that living things were not covered under §101 of the Patent Act. “If newly developed living organisms not naturally occurring had been patentable under §101,” he pointed out, “the plants included in the scope of the 1930 and 1970 Acts could have been patented without new legislation (447 U.S. 303, 320).” The majority’s opinion thus rested on the shaky “assumption that Congress was engaged in either idle exercise or mere correction of the public record when it enacted the 1930 and 1970 Acts (447 U.S. 303, 320).” But even if these acts did not dispose of the issue, Brennan maintained, the Court was exceeding its own institutional competence by extending patentability in such a radical manner. Congress alone was the appropriate entity for determining the scope of the patent laws in areas marked by uncertainty and substantial public concern (447 U.S. 303, 319).²⁷

Although the Chakrabarty decision represented a major victory for the proponents of biotechnology, the implications for agriculture, and specifically property rights over commercial plant varieties, were not immediately clear. The problem, suggested by both the majority and the dissenting opinions, was the potential overlap between the Patent

Act as extended by *Chakrabarty* and the two statutes that specifically provided patent-like protection for certain plant varieties (the 1930 Plant Patent Act and 1970 Plant Variety and Protection Act). In the absence of judicial guidance on the issue and seeking to clear up the confusion, the PTO adopted a policy that gave the 1930 and 1970 Acts pre-emptive status over the Patent Act. Subject matter that could be patented under either of those acts would not be eligible for protection under the general patent law. For the time being, *Chakrabarty* did not extend to the creation of new plant varieties, whatever the method (Kloppenburger 1988: 261-270).

Challenges to the PTO policy came quickly. Molecular Genetics, a small biotechnology firm from Minneapolis, MN, contested the PTO's policy when it was denied utility patent protection for certain claims relating to maize seeds, tissue cultures, and whole plant lines that had been manipulated to produce increased levels of tryptophan. In a 1985 hearing before the Board of Patent Appeals and Interferences, the reviewing examiners rejected the PTO's arguments that the plant-specific acts provided exclusive protection for plant life covered under the acts. Based on the principles established in *Chakrabarty*, the Board's decision, known as *Ex Parte Hibberd*, expressly allowed for the patenting of plants and their constituent parts under section 101 of US patent law (*In re Hibberd*, 227 U.S.P.Q. 443 (Bd. Pat. App. & Interf. 1985)). This proved to be an enormous step forward from the relatively weak intellectual property regime that had previously governed plant-breeding efforts (Kloppenburger 1988: 130-151, 261-270; Bugos and Kevles 1992; Seay 1993). But it was only an administrative decision, and thus had no power to bind a federal court should it be called upon to decide the issue.

Not until 1998 did the Hibberd ruling face its first test in federal court. In a case brought by Pioneer Hi-Bred against a group of local seed suppliers for allegedly infringing Pioneer's utility patents on hybrid corn seed, an Iowa district court accepted the Hibberd ruling (*Pioneer Hi-Bred International Inc. v. J.E.M. Ag Supply*, U.S. Dist. LEXIS 21782 (N.D. Iowa, 1998)). On appeal, the Court of Appeals for the Federal Circuit affirmed, holding that seeds and seed-grown plants were (and are) patentable subject matter under §101 of the Patent Act (*Pioneer Hi-Bred International, Inc. v. J.E.M. Ag Supply*, 200 F.3d 1374 (Fed. Cir. 2000)). In its opinion, the court noted that in the past plants had been ineligible for patent protection because they were "products of nature" and "could not be described with sufficient precision to satisfy the written description requirement of the patent statute (200 F.3d 1374, 1376)." Due to advances in breeding and biotechnology, both of these obstacles had been overcome:

Now, however, mankind is learning how to modify plants in ways unknown to nature. In addition, precision of description is no longer an insurmountable obstacle. . . The Court, cognizant of advances in science, has ratified the traversal of these past impediments to the compass of §101. Although there remain the traditional categories that have never been viewed as patentable subject matter, viz., laws of nature, natural phenomena, and abstract ideas, the policy underlying the patent system fosters its application to all areas of technology-based commerce (200 F.3d 1374, 1376).

In December 2001, the Supreme Court affirmed the Federal Circuit decision, using the case as an opportunity to reinforce broad patent rights for plants and plant materials

(*J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int'l, Inc.*, 122 S. Ct. 593 (2001)). Given the Court's precedent in the area and the massive growth of the agricultural biotechnology industry over the last two decades, the Court's holding that utility patents may be issued for plants under the Patent statute did not come as a surprise.

By bringing plant materials under the domain of the general patent act, *Chakrabarty* and *Ex Parte Hibberd* thus opened the door for a proliferation of patent claims on plants and their constituent parts.²⁸ Whereas the prior regime of plant protection only allowed for a single claim over a new plant variety as an indivisible whole, utility patents allowed for multiple claims, including the plant itself and various constituent parts such as genes, cells, tissue cultures, and seeds.²⁹ Such protections reflected (and reinforced) the increased specificity and control made possible by the new biotechnologies and the view of life as code. Given their improved ability to describe, isolate, and manipulate various traits and organisms, plant breeders could make an increasingly compelling case for stronger intellectual property protection.³⁰ At the same time, the lure of such stronger patent protections created added incentives for research and development.

In addition to patent protections for genetically modified life forms, biotechnology also benefited from the extension of patent protection to cover DNA sequences. Unlike the case of life forms, however, gene patenting posed no special problem for the subject matter requirements under section 101. Although genes *qua* genes, and DNA sequences in general, seemed to fall squarely within the patent law's prohibition on "naturally occurring phenomena," existing patent doctrine relating to chemical compounds provided an obvious solution. Assuming they met the other

requirements of patentability, DNA sequences qualified as patentable subject matter as long as they were purified and isolated in a manner analogous to chemical compounds.³¹ Under this standard, purified proteins, purified DNA transcripts, and even purified partial DNA transcripts would all be appropriate subject matter for patenting.³²

The implications of this transition in intellectual property protection for agriculture have only recently begun to emerge. The overall trend appears to be in the direction of increased concentration of economic power in the hands of large multinational firms – creating new risks and liabilities for various actors up and down the agro-food chain. To take one example, under the previous intellectual property regime governed by the 1970 Plant Variety Protection Act (7 U.S.C. §2321 et seq.), farmers could save seeds from their own crops to plant the following year.³³ Under the *Chakrabarty* regime, by contrast, utility patent holders can sue farmers who save seed, and over the last several years, Monsanto has done precisely that in enforcing the provisions of the technology licensing arrangement it has developed with farmers who want access to the company's proprietary traits (Mealey's Litigation Reports: Patents 2000).³⁴

Chakrabarty and *Ex Parte Hibberd* thus created a much more formal and increasingly privatized system of intellectual property protection for germplasm resources and new genetically modified organisms. With stronger intellectual property protection, incentive structures and revenue streams have shifted to favor private actors able to capitalize on the new technologies -- facilitating a race to patent valuable resources and capture the premium associated with first mover-advantages. Genomics simply reinforces this land-rush mentality, pushing private actors to further expand the number and scope of their patent claims (Enriquez 1998).³⁵ By building up a broad

portfolio of patent rights, firms seek to improve their bargaining position vis a vis capital markets and competitors, create barriers to entry for new firms, and, if the property rights become commercialized, establish new entitlement lines that will allow them to capture value along the agricultural commodity chain.

Cohen-Boyer

Unlike *Chakrabarty*, the first Cohen-Boyer patent did not involve an organism per se but rather a process for shifting bits of DNA sequence between sexually incompatible organisms. In many ways, this was the real technological foundation for the commercial biotechnology industry. As such, it was a tool that fit perfectly within the new intellectual property framework established by *Chakrabarty*. Not only were newly created organisms patentable, but the processes used to create such organisms could also be patented. Cohen-Boyer thus extended the incentives associated with privatization into the upstream reaches of the biotechnology complex. Almost all biotechnology research, to the extent that it involved a novel technique or produced a novel product, was now capable of being commercialized. The upside to this, of course, was that it created substantial incentives for innovation. The downside was that it had a potentially distortionary effect on academic research, pushing it in directions where monetary reward was most likely and undermining incentives for collaboration.

The Cohen-Boyer patent also focused attention on the fact that universities could enrich themselves by licensing the inventions for their scientists. Stanford and UCSF licensed the Cohen-Boyer patent widely, generating nearly \$200 million in royalties before it expired in 1997 (Biotechnology Newswatch 1981: 4; Rauber 1997). Cohen-Boyer illustrated the potential rewards associated with the commercialization of

university-based research – a significant departure from the model of university research that prevailed during the post-WWII period. Indeed, because of restrictions associated with federal funding, much of the research carried out in universities during the post-WWII was not amenable to commercialization. All of this changed in 1980 with passage of the Bayh-Dole Act, which allowed for the commercialization of federally-funded research.

Bayh-Dole

The basic premise behind Bayh-Dole was that the patenting of such inventions was a public good – a proposition that has stimulated significant and ongoing debate. According to the thinking that animated the legislation, the lure of patent protection would provide incentives for researchers to develop useful products that would serve the very public whose tax dollars supported that research (despite the fact that the public would essentially be paying twice for such research). In contrast to the “dead-hand” effect of public ownership where valuable discoveries and inventions would atrophy in a public sphere that lacked entrepreneurial energy, the possibility of private appropriation would result in a more efficient utilization of public money (Eisenberg 1996).

As originally conceived, Bayh-Dole was directed mainly at small businesses receiving federal funding, with the overall intention of stimulating industrial development, job growth, and international competitiveness. Universities and other non-profit organizations were of secondary concern. Yet, Bayh-Dole had a substantial impact on university research – opening the door for extensive university-industry collaboration. Moreover, although Bayh-Dole was not designed with biotechnology in mind, it had a tremendous influence on the biotechnology enterprise. Indeed, given the knowledge-

intensive character of biotechnology (and the concomitant importance of university-based scientists) and the fact that patents are so important in the biotechnology area, the interchange between universities and industry facilitated under the Bayh-Dole framework has been far more intense in biotechnology than in almost any other field. The danger is that universities will be transformed from “public goods” into special interests intent on selling themselves as engines of economic growth.

What is important about Bayh-Dole for understanding the emergence and evolution of the agricultural biotechnology complex is that it created a whole new incentive structure for university scientists and forged new pathways between public and private science – critical elements of what Martin Kenney has termed the University-Industrial Complex (Kenney 1986). As such it complemented the intellectual property regime established under *Chakrabarty*, reinforcing the tendency toward privatization of biotechnology research and creating significant incentives for universities to develop their own intellectual property portfolios and licensing strategies. Not surprisingly, many of the early biotechnology start-ups emerged directly out of the university setting, and most of the major agricultural biotechnology firms have subsequently developed strong relationships with universities in their efforts to maintain an innovation pipeline for generating intellectual property.³⁶

A New Legal Infrastructure

Taken together, *Chakrabarty*, Cohen-Boyer, and Bayh-Dole represented a new legal infrastructure for the agricultural biotechnology complex. When combined with the advances in molecular biology and genetics discussed in the previous section, the resulting economic space allowed for a major expansion in the nature and scope of

proprietary claims over biological organisms and their constituent parts. Given the increased precision and calculability made possible by the view of life as code, new legal claims could be made and enforced more easily than in the past.

In taking advantage of these opportunities, leading firms pursued a strategy of acquiring a portfolio of broad and fundamental patents relating to key commercial crops and transformation technologies with the overall goal of locking-in first mover advantages and strengthening bargaining positions vis a vis competitors. Using the new tools of biotechnology, these firms filed increasing numbers of patents throughout the 1980s -- not only on particular genes and their application in a particular plant but also on the plants themselves (as well as their seeds and the progeny of those seeds) and on the basic transformation technologies used to engineer new plant varieties. By the early 1990s, as the first major agricultural biotechnology patents began to issue, many observers expressed astonishment at the breadth of some of the patent claims.

In 1992, for example, Agracetus received a patent that included a claim covering all transgenic cotton (US Patent No. 5,159,135).³⁷ Using its proprietary “gene gun” transformation technology to create the transgenic variety, the company won the broad claim on the grounds that it was the first to show that cotton could be genetically engineered by any method.³⁸ Far exceeding the scope of patents on particular genes, seed varieties, or transformation techniques, the claim thus covered all genetically engineered varieties of an entire crop -- effectively granting Agracetus the rights to any genetically engineered cotton produced by any method until 2008. The first of its kind, the patent is still widely considered to be the broadest patent ever granted in the field of plant biotechnology (Biotechnology Newswatch 1992b: 5). Not surprisingly, it stirred

considerable controversy. Jerry E. Quisenberry, director of the Cotton Systems Research Laboratory at USDA, called the decision “very unfortunate.” “Rather than being able to release new genetically engineered cotton varieties directly to farmers, we are now forced to go to this large company and enter into an agreement with them (Quoted in Shulman 1994: 16).”³⁹ Although Agracetus pledged to license its technology widely, nothing in the law could compel it to do so. Indeed, early licenses granted to Calgene and Monsanto were restricted to work focused on improving the “agronomic” aspects of cotton. Licensees were explicitly barred from undertaking any work on altering the qualities and characteristics of cotton fibers – an area that Agracetus wanted to preserve for itself (Biotechnology Newswatch 1992: 5). This kind of licensing strategy simply reinforced the incentive to acquire strategic patents in order to improve one’s position in future licensing negotiations. To be a player in the world of genetically engineered crops, having a sufficiently broad patent portfolio was the price of admission.

As more patents began to issue and as the first products approached commercialization, the industry saw a flurry of cross-licensing deals between leading firms.⁴⁰ Many of these deals involved licenses for specific genes or traits, such as herbicide tolerance or insect resistance, while others involved specific transformation technologies.⁴¹ Because many of the newly issued patent claims were framed so broadly, particularly in the area of basic processes and inventions, it became increasingly difficult to develop new transgenic plants without infringing on patent rights of one sort or another (Barton 1998: 85-97). Cross-licensing obviously provided one way of sorting out these conflicting entitlement lines. Such agreements might be explicit or implicit (as in a tacit agreement not to sue for infringement)—highlighting the strategic importance of

acquiring patents likely to be infringed so as to enhance bargaining power (Barton 1998: 94).⁴²

Licensing could only go so far, however. As firms raced to commercialize the new technologies, recently issued patents became increasingly valuable. Given that multiple firms were often working in the same area and because the newly issued patent claims often overlapped, firms increasingly turned to litigation as a competitive tactic.⁴³ In one of the more heavily litigated areas—the case of the insect-resistance technology known as *Bacillus thuringiensis* (Bt)—a number of overlapping patents were awarded during the mid-1990s, including (1) a patent to the first firm to clone the Bt gene; (2) a patent to the first firm put the gene in any plant; and (3) a patent to the first firm to put the gene in a crop plant. Not surprisingly, as Bt products moved closer to commercialization, the breadth and overlap of the patent claims provided fertile ground for litigation and, in some cases, new incentives for consolidation (Barton 1998: 92-93, 1999: 5; Neubar 1999).

Indeed, as 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, litigation over the nature and scope of these patent claims has proliferated. Following a pattern typical of patent infringement actions, these firms often filed suit against their competitors as soon as they received a patent. Competitors usually responded with counter-claims of patent invalidity. In the case of Bt litigation, for example, more than a dozen lawsuits have been filed since 1995 involving most of the major players in the industry.⁴⁴ Although some of these suits have

subsequently been dismissed, settled, or dropped as a result of merger, several of the more important disputes have resulted in jury verdicts and, very recently, in appellate decisions.

In February 1998, for example, a federal Jury in Wilmington, Delaware rejected claims by Mycogen that Monsanto and its licensees had infringed Mycogen's 1996 patents covering the use of Bt to create insect-resistant crops.⁴⁵ The jury's decision effectively invalidated the 1996 patents, depriving Mycogen of royalties and damages exceeding \$70 million. Mycogen's stock subsequently dropped more than 20% (Fairley 1998e: 13). In March 2001, the Court of Appeals for the Federal Circuit upheld the lower court ruling (*Mycogen v Monsanto*, 2001 U.S. App. LEXIS 3729 (Fed. Cir. 2001)). Four months after Monsanto received its favorable jury verdict against Mycogen, however, another federal jury in Delaware rejected a Monsanto action against Mycogen, Novartis, and others relating to a patent for synthetic Bt genes, invalidating the Monsanto patent on the grounds of prior invention.⁴⁶ But in November 1998, Monsanto prevailed again, receiving another favorable jury verdict in a Bt patent infringement action brought by Novartis (Rubenstein 1999).

To date, the ongoing litigation over who will control the rights to Bt technology has resulted in invalidation of patents held by Mycogen, Monsanto, and Novartis. These rulings have effectively narrowed the respective portfolio of Bt patents held by these companies, suggesting that courts will likely not allow patents of very broad scope to stand. It should be pointed out, however, that to date almost 400 patents have issued with claims relating to Bt, and more are being issued all the time. As Table 2 below indicates, Mycogen alone now has 130 patents with claims relating to Bt. All of the leading

companies are also hard at work on developing the next generation of Bt technology. More important, even in the context of ongoing litigation, many of these companies are also in cross-licensing agreements with one another. It may turn out that as the industry structure stabilizes, firms will find litigation increasingly less attractive and seek out cross-licensing arrangements (explicit or implicit) (Barton 1998: 94).

But licensing agreements have sometimes led to lawsuits as well – often in the wake of mergers. In 1998, for example, a California jury ordered Monsanto to pay \$174.9 million in damages to Mycogen because of Monsanto's refusal to honor a gene-licensing agreement for Bt corn that Monsanto had negotiated with a company (Lubrizol Genetics) that was later acquired by Mycogen. In Mycogen's view, Monsanto's actions represented a deliberate attempt to lock Mycogen out of the Bt corn market (Kilman 1998b).⁴⁷ Similarly, in February 2000, a federal judge in North Carolina upheld a jury award of \$65 million to Aventis Crop Science against Monsanto subsidiary Dekalb Genetics Corp. for misappropriation and fraud stemming from a 1994 licensing agreement for herbicide tolerance technology (Delaware Law Weekly 2000a: 5; Chemical Week 2000a: 10). And, in the latest round of such litigation, DuPont filed suit in March 2000 against Monsanto alleging that Monsanto stole the key technology used to create its herbicide-resistant soybeans when it acquired Asgrow Seed Co., a company which had worked with DuPont in the late 1980s to develop the technology (Delaware Law Weekly 2000b: 5).

As the leading firm in the industry, Monsanto, along with its various subsidiaries (most notably Dekalb), has found itself at the center of much of the litigation (Monsanto 2000: 79-83). Such lawsuits can work to protect firms against entry into particular product lines by others, or conversely to open up new areas to competition. In the

process, the boundaries of economic power and the structure of the industry are being determined.⁴⁸ In effect, the courts are being used not only to clarify intellectual property claims but also to determine the boundaries between the handful of major firms that now dominate the industry. Litigation, in short, has become an important component of the strategies of these firms as they jockey for position in the emerging oligopoly.

Meanwhile, the rush to patent continues. As Table 2 below suggests, the five major firms in the agricultural biotechnology industry have amassed considerable patent portfolios in key crops and technologies. Although the table captures only a portion of the total number of biotechnology related patents held by these firms, it gives some indication of the extent of these patent portfolios and the difficulties that new firms seeking to enter the industry might face. In effect, these overlapping patent portfolios have resulted in a veritable “patent thicket” – a densely overlapping matrix of entitlement lines that operates as a substantial barrier to entry (Shapiro 2000; Barton 1998). Any new firm seeking to enter one of these areas would face the daunting prospect of trying to patent around these portfolios or trying to negotiate a sufficient number of licensing agreements with the various patent holders to avoid infringement suits.⁴⁹ Not exactly an attractive set of options.

The recent shift toward genomics will likely work to strengthen these barriers to entry. Seeking to lock up as much intellectual property as quickly as possible, industry leaders such as Monsanto and DuPont are pursuing patenting strategies based on Expressed Sequence Tags or ESTs (fragments of genes that can be used to identify and ultimately isolate the gene itself) from the genomes of major commercial crops. Through their partnerships with elite genomics firms and on the basis of their own sequencing

efforts, the major agricultural biotechnology firms are developing libraries of ESTs (and genes) for the major crops and filing patent applications as quickly possible. But patenting is still a bit of a wild card in this area. Relying on a set of tools and techniques known broadly as bioinformatics (i.e. computer assisted genetic analysis tools that infer gene functions from DNA sequences by comparing them to well-known genes in other organisms), these firms are betting that inferred gene function will be enough to support patent claims – a prospect that was reinforced in October 1998, when the PTO awarded an EST patent to Incyte pharmaceuticals. But persistent confusion regarding the PTO’s policy toward ESTs and the lack of any appellate level decisions on these kinds of claims has made the commercial viability of such a strategy somewhat uncertain (Fairley 1998f: 18; Ratner 1998: 810-11).

Table 2: Selected Ag-Biotech Patents by Assignee (cumulative through March 2001)

ASSIGNEE	Patents with claims for maize or corn plants or seeds	Patents with claims for soybean plants or seeds	Patents with claims for <i>Bacillus thuringiensis</i>	Patents with claims for plants or seeds generally
Monsanto (Dekalb, Agracetus, Calgene, Asgrow)	188	266	38	885
Syngenta (Novartis)	186	110	45	932
DuPont (Pioneer)	337	87	1	484
Aventis (Rhone Poulenc, Hoescht)	43	24	3	263

Dow (Mycogen)	43	19	130	275
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Source: LEXIS Patent Database, search by claim and assignee 3/31/01.

Indeed, patent claims on DNA sequences derived from genomics and bioinformatics are of an altogether different nature than those derived from earlier techniques of isolating and purifying single genes. Because the new sequences are essentially computer-generated information, the chemical compound analogy that provided the basis for granting gene patents in the past may no longer be appropriate (Eisenberg 2000).⁵⁰ In some respects, the considerable uncertainties relating to the application of patent doctrine in this area simply reinforces incentives to file as many patent applications as possible. For these and other reasons, the avalanche of data derived from various sequencing efforts has translated into a flood of patent applications at the PTO.⁵¹

In order to deal with the flood of new patent applications, the PTO adopted new utility guidelines in January 2001 (U.S. PTO 2001). The new rules, which have been around in draft form since December 1999, raise the bar on patentability for ESTs and other DNA sequences derived from genomics sequencing efforts by requiring that a specific claim enable at least one credible use.⁵² Simply predicting or inferring gene function may not be enough under the new rules. But the policy has yet to be tested in court and there is no guarantee that the Federal Circuit would follow it. Indeed, in a case decided in 1998, the Federal Circuit held that inventions involving the input, calculation and storage of numerical data are patentable subject matter as long as they produce a “useful, concrete, and tangible result (*State Street Bank & Trust v Signature Financial Group*, 149 F 3d 1368 (Fed Cir. 1998).” Several commentators have suggested that this

holding, together with another 1999 Federal Circuit decision (*AT&T Corp. v Excel Communications Inc.*, 172 F. 3d 1352 (Fed Cir. 1999)), may open the door to a variety of patenting strategies relating to bioinformatics and genome sequences (Alexander 1999: 395; Barton 2000: 805).

To the extent that patents do issue for genomics derived sequences, the breadth and strength of the new patent claims that result will likely have a considerable impact on the structure of the industry and the relative positions of the major players. Given the stakes involved and the uncertainties associated with the ongoing attempt to develop a workable legal framework, the potential for conflicting intellectual property claims will almost certainly increase. Yet, even if the genomics patent rush turns out to be a bust, the first movers in the area, by virtue of their initial investments, will almost certainly find ways to use the technology to leverage their existing organizational capabilities and extend their control.

Capturing Value: Business Enterprise and Industrial Integration

The cost of developing this technology is so high that companies want to capture as much of the value chain as they can to get the full margin. The trend is for companies to forward and backward integrate in this industry. I think the future is bleak for seed companies that do not have their own technology or germplasm to trade with other technology providers.

-Col Seccombe, President of Garst Seeds, 1998 (quoted in Olson 1998).

By the mid 1990s, as the first patents began to issue and as transgenic crops approached commercialization in the United States, the large agro-chemical firms acquired the handful of agricultural biotechnology start-up companies that remained (i.e. those that had managed to acquire a sufficiently strong technology platform to stay in the

business). In some instances what had started as cross-licensing arrangements evolved into controlling interest purchases and then into full-blown acquisitions.⁵³ The overall objective was to consolidate a technology platform and the associated patent rights. By 1998, there were no major independent agricultural biotechnology start-ups left.

But developing and consolidating a technology platform (and the associated intellectual property rights) was merely the first step in the effort to commercialize agricultural biotechnology. Leading firms also needed access to key germplasm resources and seed distribution systems in order to get their new products into the hands (and fields) of farmers. Acquiring prominent seed companies solved both of these problems – giving first movers such as Monsanto and DuPont access to a stock of high-quality germplasm and existing seed distribution channels in the major agricultural regions. As one industry analyst put it: “The seed companies are the key to the whole world of biotech. How do you get your seeds to the farmer? You don’t put them in an envelope and mail them. It’s through seed companies (Quoted in Barboza 1999).” Thus, the late 1990s witnessed an extraordinary concentration in the North American seed industry, with the major biotechnology firms paying very high premiums for seed companies (Steyer 1998; Shimoda 1998: 62-63). In many respects, this highlights the unique and seemingly irreducible “nature” of agriculture and the constraints that agriculture and farming place on the commercialization of agricultural biotechnology. Without a delivery vehicle capable of getting these technologies out of the lab and into the ground, agricultural biotechnology would never generate any economic value for its proponents. Vertical integration via the downstream acquisition of seed companies

provided the critical institutional vehicle for capturing value (Kalaitzandakes 1998: 40-42; Shimoda 1998; Olson 1998; Holmberg 1991: 31).

Monsanto again blazed the trail in the industry, gorging itself on an \$8 billion buying spree between 1996 and 1999 which included acquisition of major seed companies such as Asgrow, Dekalb, Holden Seeds, and Cargill's International Seed Business (Smith 1998; Rotman 1996e, 1997b; Pezella 1996; Fairley 1998d).⁵⁴ DuPont followed by completing its own acquisition of Pioneer Hi-Bred, the world's largest seed company, in a transaction valued at \$7.7 billion (Howie 1999). Novartis, which already controlled the former Northup King seed company, also pursued joint ventures with a number smaller seed companies (Olson 1998; Steyer 1998). By the late 1990s, only a handful of major players remained in the seed industry, leaving other biotechnology companies such as Aventis and Astra-Zeneca without a delivery system of their own – a fact that translated into far fewer opportunities for developing and pursuing their own commercial strategies. In response, these firms actively pursued technology-licensing pacts with seed companies – an increasingly risky strategy in light of the fact that such companies are now either controlled by or dependent upon Monsanto, DuPont, and Novartis.

As suggested in the previous section, such cross-licensing agreements are hardly new to the industry. Indeed, at the same time that leading biotechnology firms were acquiring the major seed companies, they were also developing licensing agreements with smaller independent seed companies and with their competitors.⁵⁵ Moreover, several of the seed companies that were acquired by major biotechnology companies had previously developed licensing arrangements with competitor companies. Pioneer, for

example, has licensing agreements with Monsanto for both insect-resistance and herbicide-tolerance traits that supposedly last in perpetuity and are unaffected by any change in ownership or control of Pioneer (Dow Jones Newswires 1999; Olson 1998).⁵⁶

Notwithstanding the ongoing litigation in the sector, the emerging pattern appears to be one of extensive cross-licensing among the major players in the industry. Such arrangements essentially allow companies to trade technologies. For firms such as Monsanto, Novartis, and DuPont, which control the lion's share of such technologies, this allows them to extend their market share and, in the context of licensing to independent seed companies, consolidate their hold over seed distribution networks. Given the low margins associated with farming, and particularly with commodity crops such as soybeans and corn, capturing market share is obviously the key to recouping investment costs and generating profits.

The other major advantage of acquiring seed companies was the fact that they provided a system for delivering the new technologies to farmers. The challenges here were not insignificant. If these firms simply sold the seed to farmers through traditional channels, they might not get the full return from their intellectual property. Farmers often saved seed from year to year and sometimes exchanged seed with one another -- practices which threatened to dilute the value of the proprietary traits that the biotechnology firms had invested so heavily in. The solution, it seemed, lay in contract farming – an institutional arrangement whereby farmers would be further incorporated into the vertically integrated structure of agricultural biotechnology.⁵⁷

Such an arrangement, under which farmers agree to grow certain crops under certain conditions in return for access to key inputs and, in some, cases downstream

marketing channels, has a long history in American agriculture – from sharecropping to the modern production contracts that have come to dominate certain sectors such as poultry.⁵⁸ In the new world of biotech crops, the most prominent method of contracting employed to date is the “technology licensing fee” developed by Monsanto. As the name suggests, these user agreements include a technology fee, which is attached to the sale of all seeds containing the technology. But the contracts also contain specific provisions for those who purchase the seeds.⁵⁹ In the case of Monsanto’s Roundup Ready soybeans, the licensing agreement mandates that the farmer must use only Monsanto’s Roundup-branded herbicide, despite the fact that other, cheaper herbicides containing the same active ingredients are available. The contract also prohibits the saving of seeds and includes harsh penalties for violation of the agreement, namely payment of any legal fees that Monsanto incurs in enforcing the agreement, stipulated damages of 120 times the applicable technology fee, and forfeiture of any right to obtain genetically modified seeds in the future if a violation is found to have occurred. Finally, if a violation is suspected, the provisions of the agreement require farmers to submit to inspections of their fields and records. Given the new level of precision with which biotechnology companies can identify and track their proprietary traits and technologies (i.e. the specificity with which they can identify the specific genetic sequences involved), the mechanisms needed for surveillance and enforcement of these agreements are effectively built into the technology itself.⁶⁰

If the last several years are any indication, however, many US farmers have clearly embraced Monsanto’s approach as evidenced by the rapid penetration of Roundup Ready Soybeans (Brasher 2001). The reality of contracting, though, is that farmers will

be more tightly integrated into vertically coordinated systems that are directed largely by the input suppliers. Moreover, as the number of input suppliers shrinks to only a handful of companies, all of whom control key technologies in various product lines, bargaining power clearly shifts in favor of off-farm actors. If the experience of farmers in the poultry industry is any guide, the future does not look good for those who contract for the new biotech crops (Boyd and Watts 1997).

Finally, in addition to acquiring seed companies and developing contractual relations with farmers, the leading agricultural biotechnology firms have also made some tentative efforts to move further downstream to establish linkages with food and feed processing operations. In the current climate, however, such efforts have not met with the type of success that previous efforts in other areas have. While the large grain companies are still accepting transgenic crops, they are increasingly wary of the technology and its effects on the markets they serve. Food companies and food retailers, particularly those with lucrative brand-name labels at stake, are also keeping an arms-length relationship with agricultural biotechnology. Everybody, it seems, is waiting to see what happens. As agricultural commodity markets continue to differentiate, the various downstream actors are trying to determine which segments they want to be involved in and what the costs and benefits of embracing biotechnology are for their overall businesses. Such uncertainty does not bode well for those who have invested so much in making biotechnology work.

Nonetheless, despite the ongoing uncertainty and the recent setbacks suffered by Monsanto and other proponents of agricultural biotechnology, it is quite clear that the leading firms in the industry have already brought about a substantial restructuring of the

agro-food system -- resulting in a remarkable concentration of strategic assets in the hands of only a few major companies. Over the last couple of years, some of these structural concerns have become the subject of heightened government scrutiny, largely through congressional hearings and antitrust investigations by the Justice Department (Harl 1999; FTC Watch 2000). At the same time, a number of private antitrust lawsuits have also been filed in recent years, directed almost exclusively at Monsanto. In 1998, for example, British biotechnology company Zeneca filed an antitrust lawsuit against Monsanto in US Federal Court in Delaware. The suit alleged that Monsanto was using its control of glyphosate-tolerant crops to “effectively foreclose” Zeneca’s sale of its own glyphosate-based herbicide (Chemical Week 1998: 6; Fairley 1998g). In December 1999, a group of high-profile plaintiff’s lawyers filed an international class-action lawsuit alleging that Monsanto and its “co-conspirators” had attempted to monopolize the transgenic corn and soybean markets and conspired to restrain trade and fix prices in these markets.⁶¹ Finally, in March 2000, DuPont filed two antitrust lawsuits in two different federal courts alleging that Monsanto had “used a variety of illegal means to monopolize” the herbicide, soybean seed, and cottonseed markets.⁶²

Of course, it may turn out that none of these lawsuits have any merit. Still, the overarching fact of substantial concentration in the sector remains – raising a host of concerns about the desirable level of concentration and competition in a sector as important as agro-food. This is the problem of monopoly, and it has a long history in agriculture. What makes the contemporary context so challenging and so important is that the problem today derives not from estates in land as in the past, but rather from proprietary control over the power of heredity.

Conclusion

We are learning about biology at a level and at a rate that is absolutely unprecedented in human history. There is an enormous potential space to be filled, and the stakes are very high. We want to be able to occupy and hold the most valuable territory.

-Robert Shapiro, CEO Monsanto Co., 1998 (quoted in Kilman 1998a).

We did proceed on the basis of our confidence in the technology. And we saw our products as great boons both to farmers and to the environment. I guess we naively thought that the rest of the world would look at the information and come to the same conclusion.

-Robert Shapiro, CEO Monsanto Co., 1999 (quoted in Kilman and Burton 1999).

What a difference a year makes. For a company that seemed to be making all the right moves, at least as far as Wall Street was concerned, the turnaround in Monsanto's fortunes has been stunning. Facing increased consumer resistance to biotechnology and a mounting debt burden stemming from its three-year \$8 billion acquisition spree, Monsanto saw its share price plunge in late 1998 and 1999, forcing the company to seek out a partner with deep pockets. The so-called "merger of equals" with Pharmacia emphasized the company's pharmaceutical assets rather than its leadership position in agricultural biotechnology. Indeed, the agricultural side of Monsanto's business seemed to be more of a liability than an asset in the eyes of investors, forcing the newly merged company to propose a partial spin-off of the agricultural operations in an effort to liberate its share price (Deogun et al 1999).

This hardly spells the end of agricultural biotechnology, however. Companies may be changing hands and agricultural units may be spun off. R&D spending also appears to be leveling off, at least for the time being. But the general structure of the

industry is still in place, and efforts to commercialize the technology, particularly in the area of output-oriented traits, continue. Barring any major divestment of assets, the bottom line is that a handful of companies now own many of the key property rights, most of the elite germplasm, and the basic seed delivery systems that have supported the major oilseed, corn, and grain producing regions in North America and elsewhere for much of the post World War II period. In the end, the precise identity and ownership structure of these companies does not really matter as long as the strategic assets are concentrated in so few hands. This obviously raises important governance questions that are quite distinct from those currently dominating the public agenda (i.e. labeling and bio-safety).

As this essay has argued, such concentration derived from powerful monopolistic tendencies embedded within the deep structure of the agricultural biotechnology enterprise – specifically, the synergistic relationships between the increased precision and calculability in the science of genetics and the techniques of genetic manipulation, a stronger intellectual property regime for life forms, and the biological and social facts of agriculture. Drawing on the metaphor of life as code and the interventionist possibilities associated with recombinant DNA techniques, leading agricultural biotechnology firms developed considerable capabilities for creating “novel” life forms during the 1980s. When combined with the stronger intellectual property regime for such life forms that took shape in the early 1980s (largely in response to the scientific and technical advances associated with biotechnology) acquisition of property rights emerged as a central component of the overall strategy. Pursuing such a strategy obviously entailed substantial capital investment, adding to the imperative of developing an organizational structure

capable capturing the value associated with these new technologies. Because proprietary traits had little value without access to existing germplasm and seed delivery systems for key commercial crops and because farmers were necessary to provide the critical “grow-out” stage in order for firms to capture the value associated with their proprietary technologies, vertical integration proved to be the key institutional vehicle for capturing value. Thus, leading firms, particularly Monsanto and DuPont, acquired major seed companies and developed a system of contract farming tailored to the new biotech crops.

In the process of building such organizational capabilities around their proprietary technologies, however, these firms also found themselves confronting an increasingly dense “patent thicket.” As individual firms acquired vast numbers of patents in particular areas, competitors had little choice but to respond with similar strategies. This strategy of patent portfolio racing seemed to derive less from the need to incent innovation than from the defensive need to protect one’s own bargaining position vis a vis competitors. Because many of the basic patents issued in agricultural biotechnology contained overlapping and competing claims, firms often found themselves facing a situation of conflicting entitlement lines. In some cases, firms litigated to try and sort out these conflicting entitlement lines. In others, they pursued cross-licensing agreements or mergers. In the end, only those firms with substantial patent portfolios and sufficient organizational capabilities remained.

Looking back at the remarkable development of the industry over the last two decades, it is clear that the nature and scope of the patent rights involved in agricultural biotechnology have been instrumental in driving consolidation (vertical and horizontal) in the sector. Such a concentration of strategic assets in so few hands raises a number of

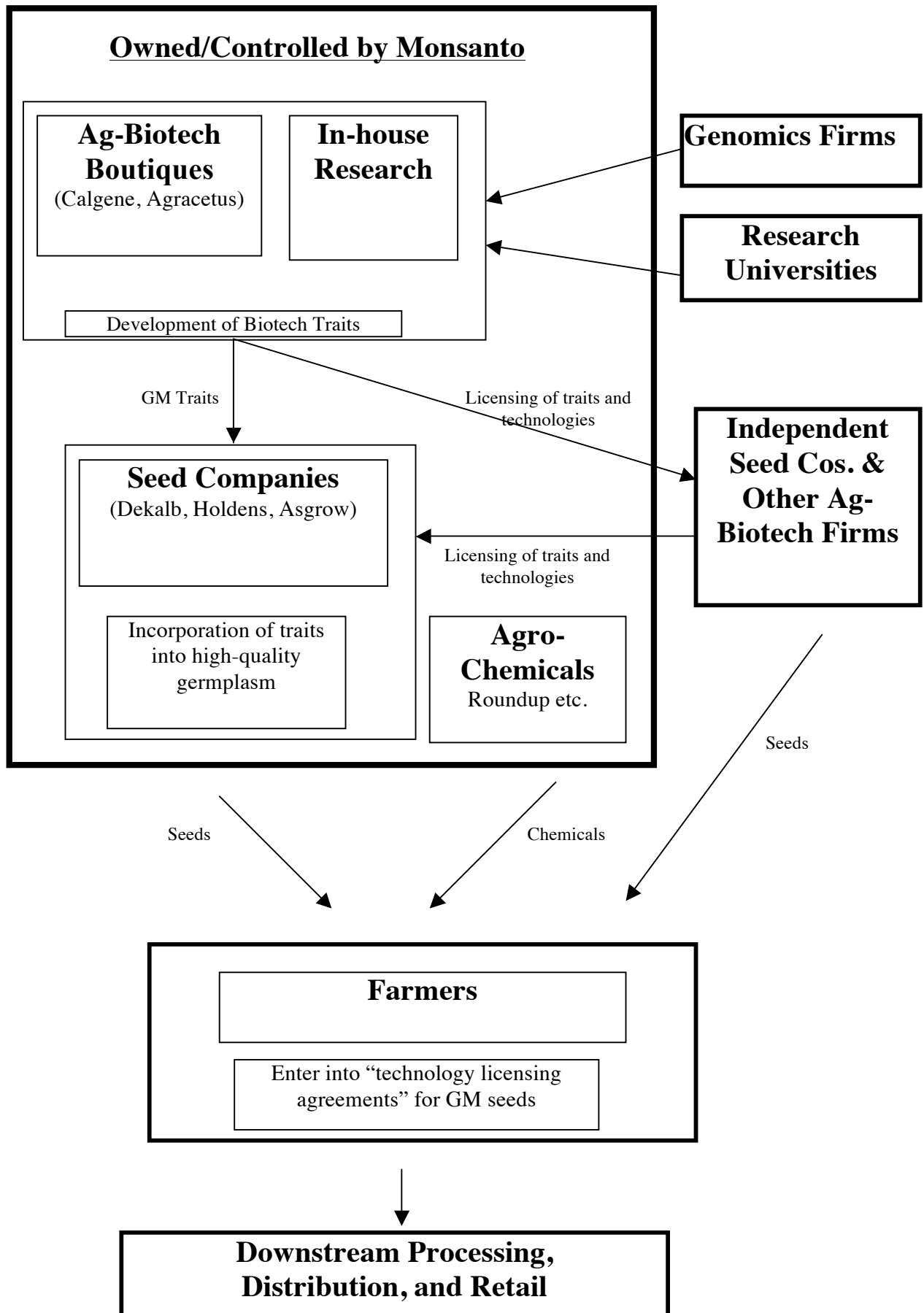
important public policy issues. At the very least, these developments suggest the need for a rethinking of basic patent issues in the sector and stronger antitrust oversight.

Economic concentration and the associated development of new legal protections in the agricultural input sector (notably seeds and chemicals) also has important implications for farmers. Facing a dwindling set of suppliers and finding themselves locked into more tightly coordinated vertical production systems, farmers and their representatives have expressed growing concern over what they see as a loss of bargaining power and diminished economic autonomy. While such concerns have a long history in American agriculture, by extending the nature and scope of proprietary control over basic inputs/technologies such as seeds, agricultural biotechnology appears to have created an altogether new set of contractual liabilities for farmers.

Finally, although well beyond the scope of this essay, agricultural biotechnology, together with the rapid consolidation of the sector over the last decade, poses a number of important issues for consumers. The notion that the basic food supply is controlled by a handful of multinational companies is profoundly unsettling to certain segments of the American public. The world, it seems, is not ready for agricultural biotechnology. Indeed, whatever one ultimately thinks of Monsanto and its strategy for commercializing agricultural biotechnology, there can be little doubt that the company severely underestimated the level of resistance it would face from consumers. In retrospect it was a significant (perhaps colossal) miscalculation. Consumers, obviously, are the critical link in the chain that allows the capital invested in the biotechnology enterprise to circulate and, ultimately, generate profits. Blinded by its own technological enthusiasm

and ambitions of creating an agricultural biotechnology superpower, Monsanto failed to appreciate the deep cultural and political salience of food.

Appendix: Ag-Biotech Firm Structure (Monsanto example) circa 1999



¹ In 1904, Hays became undersecretary of agriculture, but continued on as secretary and “guiding force” of the ABA. Hays often compared heredity or “breeding power” to electricity and always alluded to its potential as an economic force: “As electrical energy must be harnessed, so these investigations are showing that the peculiar breeding potencies of the rare plant or animal must be singled out and given opportunity to work. Both in practical breeding and in evolutionary studies the individual with exceptional breeding power is gaining respect. . . The world is learning to seek the “Shakespeares” of the species with the same avidity that it seeks gold mines” (Hays 1906: 158). For further discussion of Hays and his role in the ABA, see Kimmelman 1983 and Paul and Kimmelman 1988.

² Given the controversies and uncertainties surrounding GEO crops, particularly in major export markets such as Europe, some farmers appear to be less enthusiastic than in the past about planting GEO crops. According to the USDA, the amount of acreage US farmers planted with GE corn declined from 25 million acres last year to slightly less than 20 million this year. The acreage devoted to other GE crops, notably cotton and soybeans, continued to expand, though apparently not as rapidly in the past (Wall Street Journal 2000).

³ Of the four principal transgenic crops grown in 1999, soybeans and corn accounted for about 82% of the total global acreage. In terms of traits, herbicide tolerance accounted for roughly 71% of global acreage while insect resistance accounted for 22% and stacked traits of insect resistance and herbicide tolerance accounted for about 7% (James 2000).

⁴ Germplasm refers simply to the total genetic material contained in a cell. In this case, germplasm is more broadly understood as the total genetic stock of the commercially valuable crops – a product of centuries of selective breeding and improvement. Such resources are critical to the biotechnology companies because their traits are essentially useless if they are not engineered into elite varieties that contain all of the other valuable traits accumulated from prior breeding efforts.

⁵ Monsanto noted that in 1999 its Roundup Ready Soybeans accounted for more than 50% of the total US soybean crop and over 80% of the Argentine crop (Monsanto 2000: 65).

⁶ The concept of “industrial order” is taken from Herrigel (1996). Herrigel describes his own methodology as “constructivist,” wherein the “organizational and governance forms that shape production, including the institution of the firm itself, are viewed as outcomes, not the starting points, of historically specific social, economic, and political conflicts about the structure of the social division of labor” (Herrigel 1996: 3). Such a perspective emphasizes the embedded and constructed character of industrial systems or industrial. The relevance of this perspective for this essay is simply that there is nothing pre-determined about the organization of the agricultural biotechnology complex. The “deep structure” or architecture of this complex is instead a product of active construction rather than the unfolding of some particular industrial logic. This is not to say, however, that such industrial constructions are entirely contingent. Certain industrial strategies and organizational forms are clearly more competitive than others. First-mover advantages are very real indeed. The point, though, is that these advantages are made rather than arrived at. Once achieved, firms will try desperately to maintain and extend such advantages. In the context of agricultural biotechnology, this has culminated in powerful tendencies toward monopolistic organization and practice.

⁷ In its first foray into the field, Monsanto purchased a \$20 million interest in Swiss-based biotechnology company Biogen NV in 1980 and announced plans to build its own biotechnology research center at company headquarters in St. Louis. At the same time, Dow chemical announced a similar deal with US-based Collaborative Genetics. Given the novelty of recombinant DNA technology, the primary purpose of these deals was to provide training in recombinant DNA techniques to company scientists (Chemical Week 1980: 17).

⁸ DuPont dedicated a \$65 million agricultural chemicals facility in Wilmington and increased its annual life sciences spending to roughly \$250 million per year. Ciba-Geigy (later Novartis) established a research facility to house its worldwide agricultural biotechnology effort in Research Triangle Park, NC (Trewitt Bluestone 1985: 34).

⁹ *Bacillus thuringiensis* (Bt) is a naturally occurring bacterium found in soil. Bt produces a protein that kills certain crop-destroying insects such as the European corn borer (a pest that costs American farmers an estimated \$1 billion a year in losses). When eaten by these insects, the Bt protein (which is not harmful to

humans and many other bugs) dissolves the insects' stomach linings, causing the insects to die. While farmers have sprayed their crops with pesticides like the Bt protein for years, such practices are only partially effective and can add significantly to farmers' costs. Inserting a Bt gene into a plant and thereby making it possible for the plant to produce its own Bt pesticidal protein would effectively give the plant an endogenous or built-in defense against insects. For a discussion, see the recent opinion of the Federal Circuit, *Mycogen v. Monsanto*, 2001 U.S. App. LEXIS 3729, 7-10 (Fed. Cir. 2001).

¹⁰ In 1988, for example, two biotechnology companies, Agracetus and Biolistics, announced independently that they had developed a new gene delivery technique known as the "gene gun". The technology used an electrical charge to blast minute metal particles coated with DNA directly into the cells of a plant. If effective, the technology promised to accelerate plant genetic engineering by allowing for more efficient gene insertion into plants. Over the next decade, the "gene gun" approach would become the leading tool for developing transgenic plants. While both companies applied for patents on the guns, Biolistics planned to make its gun widely available – signing 10 year licensing agreements with eight US companies and universities. Agracetus, in contrast, sought to keep its gun in house – contracting to perform gene insertion for other companies (i.e. companies would provide the plants and genes and Agracetus would do the insertion and return the newly engineered plants to the companies) (Spalding 1988: 16).

¹¹ All of these firms were racing to the Patent & Trademark Office with patent applications on these new inventions. It was not until the early to mid-1990s that such patents began to issue, however.

¹² The guidelines focused on product characteristics rather than process, and stated that there was no need for pre-market review of any product if substantial equivalence to existing products could be demonstrated. In a preview of the political battles to come, environmental groups expressed anger at the decision, calling for more extensive regulatory oversight, labeling, and right to know (Biotechnology Newswatch 1992a: 1).

¹³ Genomics refers to the sequencing of an organism's genome (that is all genetic material in the chromosomes of that particular organism) and the determination of the number and relative positions of individual genes on the chromosomes.

¹⁴ Bioinformatics refers to computer assisted genetic analysis tools that infer gene functions from DNA sequences (generated through genomics efforts) by comparing them to well-known genes in other organisms.

¹⁵ The basic technique focused on identifying Expressed Sequence Tags (ESTs) – snippets of DNA from active genes – which could then be used to identify genes and, using the tools of bioinformatics, infer gene function.

¹⁶ The Incyte deal was extended in 1997 and provided Monsanto with non-exclusive rights to Incyte's genomic technologies. In return, Incyte received royalties on sales of products developed under the deal (Rotman 1997: 14).

¹⁷ In addition to these collaborations, Monsanto has also developed smaller alliances with other genomics firms and university-based scientists. According to the company's S-1 Prospectus filed October 17, 200, Monsanto has, in addition to its own in-house capabilities, collaborative genomics arrangements with four principal companies (Millennium, Incyte, Mendel Biotechnology, and Paradigm Genetics). The company also notes that it has "[h]undreds of agreements with universities [that] provide [it] . . . with licenses or options to license [many of which are exclusive] genomic technologies" (Monsanto 2000: 69).

¹⁸ According to one estimate from 1998, Monsanto's library of genetic information doubles every 12 to 24 months. (Feder 1998). As of 1998, Pioneer and DuPont claimed to have a combined EST database representing more than 75% of corn's 80,000 genes [an interesting number given the recent report that humans only have 30,000 to 40,000 genes]. According to Forest Chumley, DuPont manager for technology partnerships and alliances, "We've built the capability to get all the genes in a bottle. Now the focus turns to choosing which ones to use" (quoted in Fairley 1998f).

¹⁹ This stems from the massive increases in computational capacity that have paved the way for high-throughput screening of plant and animal genomes. In theory, genomics allows for more rapid development of valuable transgenic traits while providing companies with expanded predictive ability in plant breeding, thereby promising to speed up the entire process of isolating traits and transforming them into commercially valuable products. This is obviously true for traditional breeding efforts as well as for breeding efforts utilizing recombinant techniques (Holmberg 2000).

²⁰ In addition to identifying genes for use in genetic engineering, genomics is also being used to accelerate traditional breeding programs – allowing selective breeding to proceed more precisely on the

basis of genotype rather than phenotype. Through the use of genetic markers and screening technologies, breeders can ensure that their efforts transfer desirable traits. This provides a possible way to bypass many of the cultural and political hurdles associated with GM crops, and may turn out to be the most valuable use of the technology. (Fairley 1998f: 18).

²¹ Take the example of Monsanto. Drawing on its staff of over 400 scientists, the company now has the capability of conducting over 20,000 independent plant transformations (gene insertions) every year. Through its in-house genomics staff of more than 500 scientists and through collaborative arrangements with some 200 additional scientists and with an R&D budget of close to \$700 million, Monsanto has also developed the leading genomics capability in the sector. The overall objective is to discover new genes that will create new commercially valuable traits (insect and disease resistance; drought/heat/cold tolerance; improved yield; and enhanced nutritional content). In addition to providing critical inputs into its genetic engineering efforts, Monsanto is also using its genomics capabilities to accelerate and improve traditional plant breeding. In 1999, company scientists analyzed over 2.5 million genetic characterizations on crop samples. When combined the company's plant breeding platform – 1,000 people located at over 150 breeding stations in more than fifteen countries managing over 3.5 million test plots per year – the capabilities are truly awesome. Such comprehensive gene-to-seed capabilities, protected by a growing arsenal of patent rights, give Monsanto and the handful of companies that have acquired similar capabilities, considerable power in determining the shape and direction of the industry (Monsanto 2000: 67-70). All figures are for the 1999 fiscal year.

²² The formal name was *Process for Producing Biologically Functional Molecular Chimeras*, (First Cohen-Boyer Patent) United States Patent 4,237,224, December 2, 1980.

²³ 35 U.S.C. §101 provides that, "Whoever invents or discovers any new or useful process, machine, manufacture, or composition of matter or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title." Prior to this decision, numerous patents were issued on single-celled organisms that were part of an industrial process such as food processing, fermentation, and pharmaceutical development. By declaring that the newly engineered bacterium was patentable *sui generis*, however, the Chakrabarty decision represented a significant departure from past practice – giving the patent holder a much broader scope of legal protection. For a brief discussion of the history of patents on life forms, see Krimsky 1991: 45-49 and Kevles 1998.

²⁴ The basic requirements for patentability are found in the Patent Act, at 35 U.S.C.A. §§100 et seq. Briefly, to obtain a patent, the inventor must demonstrate utility, i.e. it must be a "new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof" (§101); novelty (§102), and non-obviousness (§103) (as well as meeting a host of other statutory bars under §102). The patent application must also fully describe (disclose) the invention (§112) so that the public receives the benefit of the new knowledge that the patented invention represents. If the Patent & Trademark Office agrees that these criteria have been met, it issues a patent giving the inventor, for a term of twenty years from the date that the application was filed, "the right to exclude others from making, using, or selling the invention throughout the United States" (§154).

²⁵ Jaffe (1999) identifies four major policy changes that have strengthened and extended patent protection since the 1980s: (1) the 1982 creation of the Court of Appeals for the Federal Circuit to review patent cases; (2) the extension of patenting and licensing privileges to inventors in universities and government laboratories using federal funding; (3) the extension and clarification of patentable subject matter into new areas, particularly software and gene research; and (4) international agreements under the GATT framework to extend and harmonize patent protection around the world.

²⁶ The 1930 Plant Patent Act provided protection for asexually (clonally) propagated plants, thus applying only to fruit trees and nursery plants. The 1970 Plant Variety Protection Act allowed for slightly stronger intellectual property protection for sexually reproduced plant varieties – protecting owners of novel seed varieties against unauthorized sales of their seed for replanting purposes (Plant Patent Act, 35 U.S.C. §161 et seq.; Plant Variety Protection Act, 7 U.S.C. §2321 et. seq.). As Justice Brennan pointed out, §2402(a) of the 1970 Act specifically excluded bacteria from coverage. 447 U.S. 303, 321.

²⁷ In Brennan's words: "[t]he patent laws attempt to reconcile this Nation's deep-seated antipathy to monopolies with the need to encourage progress. Given the complexity and legislative nature of this task, we must be careful to extend patent protection no further than Congress has provided. In particular, were there an absence of legislative direction, the courts should leave to Congress the decisions whether and how

far to extend the patent privilege into areas where the common understanding has been that patents are not available.” 447 U.S. 303, 319 (citations omitted).

²⁸ Since the Patent Board’s Hibberd ruling, the PTO has issued more than 1800 utility patents for plants, plant parts, and seeds (figure cited in *J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int’l, Inc.*, 122 S. Ct. 593, 596 (2001)). Note that this figure does NOT include patents on plant genes and DNA sequences.

²⁹ Kloppenburg (1988: 263-264) notes that “[t]he ability to make multiple claims significantly broadens the protection afforded the invention. It also permits the licensing of particular components – e.g., a gene for herbicide tolerance – for use by third parties. Because genetic engineering in plants is geared to transformations at the cellular and molecular levels, utility patents provide a significant advantage over PVP [Plant Variety Protection] certificates, which can provide property rights only in the whole organism.”

³⁰ Bugos and Kevles (1992: 76) argue that “the development of biological science has played a special role in the creation of intellectual property in plants. The quality of the property has turned on the intergenerational unity that breeders have been able to achieve; and the degree of protection that can be provided has depended heavily upon the specificity with which the property can be biologically described.”

³¹ See *Amgen v. Chugai Pharmaceutical Co.*, 927 F. 2d 1200 (Fed. Cir. 1991), in which the Federal Circuit stated that “A gene is a chemical compound, albeit a complex one, and it is well established in our law that conception of a chemical compound requires that the inventor be able to define it so as to distinguish it from other materials, and to describe how to obtain it. . . . We hold that when an inventor is unable to envision the detailed constitution of a gene so as to distinguish it from other materials, as well as a method for obtaining it, conception has not been achieved until reduction to practice has occurred, i.e. until after the gene has been isolated.” In order to create “isolated and purified” (and therefore patentable) DNA sequences, scientists first isolate and clone the specific gene of interest. Because the “naturally occurring” gene contains extraneous DNA that is not essential to the gene’s function in coding for a particular protein, scientists then remove these extraneous sequences (known as introns) to create a “new” stripped-down version of the gene. Because this new version, which is based on copy-DNA or cDNA (i.e. a human-made copy of the gene’s coding sequences), is not found in nature, it is patentable as long as it meets the other requirements of the Patent act.

³² The advent of genomics, however, has placed new strains on the patent system’s approach to DNA sequences, undermining the applicability of the chemical compound analogy. In short, as chemical specificity gives way to informational specificity, it is not at all clear that existing patent doctrine will be able to adapt (Eisenberg, 2000).

³³ In a 1995 decision concerning ability of farmers to sell “saved seed” under the Plant Variety Protection Act, the Supreme Court held that §2543 of the Act permitted a farmer to sell for reproductive purposes “only such seed as he has saved for the purpose of replanting his acreage.” *Asgrow Seed Company v. Winterboer*, 513 U.S. 179, 192 (1995).

³⁴ On March 29, 2001, a Canadian judge ordered a farmer to pay damages to Monsanto for patent infringement after canola plants containing the company’s proprietary herbicide tolerant trait were found growing in his field. The ruling was considered a major victory for Monsanto and other large agricultural biotechnology firms seeking to ensure that farmers will continue to pay licensing fees to use their technology (Kaufman 2001).

³⁵ Enriquez (1998) notes that the number of patent requests for nucleic acid sequences increased from 4000 in 1991 to 500,000 in 1996 largely as a result of genomic sequencing efforts).

³⁶ According to its recent prospectus, Monsanto has “hundreds of agreements with universities” which provide the company “with access to emerging genomics technologies and capabilities developed by top university scientists.” According to the company, “[m]ost of these agreements provide [Monsanto] with licenses or options to license developed technologies. Many of these licenses are exclusive (Monsanto 2000: 69).” The recent agreement between Novartis and UC-Berkeley is another example.

³⁷ The formal name is *Genetic engineering of cotton plants and lines*, US Patent No. 5,159,135, issued Oct. 27, 1992.

³⁸ In 1994, Agracetus received a European patent of similar scope covering genetically engineered soybeans. As with its broad transgenic cotton patent, Agracetus won the broad claim on the basis that its scientists were the first to show that the species could be genetically engineered by any method. In theory, the patent would require any company or researcher interested in genetically engineering soybeans to arrange licensing from Agracetus. In a rather odd affinity of interests, Monsanto and several public interest groups separately challenged the Agracetus patent. But whereas the activist groups argued that patent

protection for major food crops was morally wrong, Monsanto, careful to note that it did not object to patents in the agricultural area, objected to the excessively broad coverage of the patent (Biotechnology Newswatch 1994: 5).

³⁹ In response to such criticism, the PTO agreed in 1994 to a formal reexamination of the patent. USDA also mounted legal challenge to the patent on the grounds that it was over-broad. Meanwhile, Agracetus began pursuing patents similar to the one granted in the US in other major cotton-producing regions, including Brazil, China, and India (Shulman 1994: 16). In December 1994, the PTO suspended the patent. The issue is currently in appeal.

⁴⁰ In 1993, for example, Monsanto and Calgene signed a series of cross-licensing deals to head off potential patent conflicts involving Monsanto's Bt technology and Calgene's anti-sense RNA technology. According to Calgene, the deal would allow both firms to "focus on commercializing products rather than engaging in costly litigation (Chemical Week 1983: 30)." Although it is very difficult to determine the actual extent of licensing in the industry, it is clear from litigation and SEC filings that most of the key technologies: herbicide tolerance; insect resistance; and gene insertion techniques were the subject of extensive licensing among various companies.

⁴¹ In 1996, for example, Dekalb and DuPont entered into cross-licensing arrangement whereby each was granted access to the other's proprietary transformation technologies. According to Bruce P. Bickner, Dekalb's Chairman and CEO, "A license to DuPont's gene gun, which complements Dekalb's proprietary transformation technology is an important step toward ensuring freedom to commercialize Dekalb's pipeline of transgenic seed products (Biotech Patent News 1996)."

⁴² Barton (1998: 94) describes explicit cross-licenses as situations where "each firm permits its cross-licensee to use certain of its own basic technologies in return for the right to use the cross-licensee's basic technology" and implicit cross-licenses as situations where "the possibility of a suit is countered by the threat of a counter suit, leaving each party relatively free to use the other's technology." In light of these practices, Barton (1998: 94) concludes that "it may be as important for a firm to obtain patents that others are likely to infringe as to obtain patents to protect its own proprietary position" in order to bolster its bargaining power in the cross-licensing context.

⁴³ Barton identified more than 20 disputes involving almost 30 different patents occurring between 1991 and 1997 (Barton 1998: Table 8-1 and 8-2, 88-91).

⁴⁴ In May 1995, the same month that EPA gave Monsanto regulatory clearance for the first full commercialization of an insect-resistant plant (Bt potatoes), Mycogen's plant science subsidiary filed suit against Monsanto in federal district court in California alleging infringement of a recently issued patent covering a process for making BT plants. Mycogen claimed that its process patent (granted in January 1995) covered methods of modifying the Bt genes to make them more efficient in producing insect-resistant proteins in plants, and that Monsanto was infringing the patent with its insect-resistant cotton and potatoes as well as with products in development. The suit was filed after the companies failed to reach an agreement on licensing (Rotman 1995: 9). In March 1996, Monsanto received a patent for genes encoding Bt proteins in plants and immediately filed an infringement action against Mycogen and Ciba-Geigy (the predecessor company to Novartis) in US District Court in Delaware alleging that Mycogen's and Ciba's Bt corn seeds violated the patent (Rotman 1996a: 12). In a sign of how much importance Wall Street attached to these patent rights, Mycogen's stock promptly dropped more than 20% (Biotechnology Newswatch 1996: 4). Three months later, in June 1996, Mycogen filed suit for breach of contract against Monsanto in state court in California – claiming that Monsanto had refused to honor a 1989 contract that required it to license herbicide-tolerant gene technology for corn and cotton and Bt insect-resistant gene technology for corn to Mycogen. Meanwhile, Mycogen was itself the target of a lawsuit filed by Dekalb Genetics – alleging that Mycogen's Bt-based insect resistant seed corn product infringed on recently issued Dekalb patents (Chemical Week 1996b: 33). In September 1996, Dekalb filed a series of complaints in US District Court in for the northern district of Illinois alleging infringement of two patents on insect resistant (Bt) corn (US Patent No.'s 5,484,956 and 5,489,520) by Pioneer, Ciba-Geigy, Mycogen, Agrigenetics Inc., and Northup King. In counterclaims, Ciba and Mycogen contended that the patents were invalid (Mealy's Litigation Reports: Intellectual Property 1996). In November 1996, Mycogen renewed its patent battle with Monsanto – claiming that two broad new patents gave it a primary position relating to the use of Bt insect resistance genes in plants. Mycogen's suit against Monsanto and its partners DP&L and Dekalb alleged that their potatoes, cotton, and hybrid seed corn violated the new patents (Lehrman 1996: 12). In February 1997, Novartis filed suit in federal district court in Delaware against Monsanto and Dekalb

Genetics for allegedly infringing on its newly issued patent for Bt corn seeds. Novartis also filed a similar action against Pioneer Hi-Bred in US District Court in Minnesota (Mealey's Litigation Reports: Intellectual Property 1997).

⁴⁵ The jury verdict of patent invalidity by virtue of prior invention was upheld by the district court in September 1999 (*Mycogen v. Monsanto*, 61 F. Supp. 2d 199 (D. Del., 1999)).

⁴⁶ The jury found that while the patent was literally infringed by defendants Novartis, Mycogen, and Agrigenetics, it was not enforceable due to a finding of prior invention. In September 1999, the district court affirmed the jury's verdict. (*Monsanto v Mycogen*, 61 F. Supp. 2d 133 (D. Del., 1999)). The matter is currently on appeal before the Court of Appeals for the Federal Circuit.

⁴⁷ In June 2000, an appeals court reversed the jury verdict and in November 2000, the California Supreme Court agreed to hear Mycogen's appeal (Sissell 2000a; 2000b).

⁴⁸ Barton (1999: 5) notes that some of the mergers in the industry have also been driven by the need to settle or avoid patent litigation.

⁴⁹ Such a firm could also try to challenge such patents on the grounds of invalidity, but this would be a very timely and expensive tactic.

⁵⁰ Eisenberg (2000) distinguishes between patents on DNA molecules and patents on DNA sequence information stored in computer-readable media and concludes that the chemical analogy used to justify patents on isolated and purified DNA sequences no longer applies in the genomics era..

⁵¹ According to Enriquez (2000: 11), in 1991 the PTO received patent applications for 4000 DNA sequences. By 1996, with the advent of genomics, the number had soared to half a million. He goes on to note that in 1998, GenBank, the public gene sequence depository at the NIH that receives sequence information for all organisms, was receiving as much data every ten days as it did during its first decade of existence.

⁵² Credible uses might include a probe for a particular gene, a marker for a particular genetic trait, a diagnostic, or a sequence that encodes for a protein having a particular function (Crane et al 2000: 39; Barton 2000: 805; Doll 1998: 689; Gold 2000: 1319; and Grisham 2000: 921).

⁵³ Thus, beginning in 1995, Monsanto bought a 49.9% stake in Calgene for \$150 million – giving it more secure access to Calgene's technology (Chemical Week 1995: 25). In April 1996, Monsanto purchased the transgenic plant business of W.R Grace subsidiary Agracetus, giving it control over Agracetus's important technology for genetically modifying plants, including its "gene gun" technology, which Monsanto had been licensing since 1991, as well as the broad Agracetus patents on transgenic cotton and soybeans. The deal also resolved a long-running patent dispute between the two companies regarding an Agracetus patent covering disease protection in plants (Rotman 1996c: 8). In June 1996, Monsanto strengthened its cross-licensing arrangements with Calgene, giving it access to Calgene's technology for increasing oils content in corn, soybeans, and sunflowers (Rotman 1996d: 10). Two months later, Monsanto took a controlling interest in Calgene – boosting its stake from 49.9% to 54.6% -- for \$50 million (Chemical Week 1996a: 5). And in April 1997, Monsanto acquired the remaining 46% of Calgene for \$240 million (Biotechnology Newswatch 1997: 2). Likewise, beginning in 1996, Dow Chemical began acquiring an ownership interest in Mycogen. In July, DowElanco, the agricultural chemicals joint venture b/w Dow Chemical and Eli Lilly, took a 46% stake in Mycogen for \$126 million (Rotman 1996b: 9). The following February (1997), Dow took a controlling share of Mycogen – increasing its stake from 46% to 52% -- thereby securing control over one of the most coveted patent portfolio's in the plant biotech business (Stringer 1997: 55). And in January 1998, four days before jury selection began in the Monsanto/Mycogen Bt patent litigation in Delaware, Dow increased its stake in Mycogen to 63% (Fairley 1998a: 10).

⁵⁴ Monsanto also attempted a \$1.8 billion stock deal for the Delta Pine & Land Co. in 1998, the leading US cotton seed company and owner of the infamous terminator technology. When combined with Monsanto's own cottonseed operations, the Delta Pine & Land deal would have given the company control over some 80% of the market for cottonseed. The deal was never consummated because of antitrust concerns (Kilman 1999; Guidera 1999). Antitrust concerns were also raised in connection with the Dekalb acquisition. In December 1998, the Department of Justice approved the deal subject to two conditions. First, Monsanto agreed to donate the rights to agro-bacterium mediated genetic transformation in corn to UC-Berkeley. This was an emerging technology for placing new genes in plants and it generated antitrust concerns because of the strong patent rights held by Dekalb and Monsanto over other transformation technologies. Second, Monsanto guaranteed continued access via licensing to corn germplasm for 150 seed

companies that are currently customers of Monsanto subsidiary Holden's Foundation Seeds. According to Joel Klein, head of the DOJ antitrust division, "The spin-off of the transformation technology and the wide licensing of corn germplasm will preserve competition in this newly emerging market for corn with transgenic improvement. Competition in biotechnology ensures that American farmers have access to the latest innovations in seed technology (Fairley 1998c: 12; Andrews Mergers & Acquisitions Litig. Rep. 1998)."

⁵⁵ Monsanto, for example, licenses its proprietary traits to more than 300 small seed companies in North America (Monsanto 2000: 72).

⁵⁶ In March 2001, however, a federal district judge in St. Louis ruled that certain license agreements between Monsanto and Pioneer relating to Roundup Ready soybeans and Roundup Ready canola did not survive the acquisition of Pioneer by DuPont in October of 1999. DuPont has appealed and promised to continue marketing the technologies during the appeal process (Dow Jones Newswires 2001).

⁵⁷ The other method of capturing value associated with these transgenic seeds, of course, is simply to charge premium for the seed. Companies generally use a mix of these strategies. Monsanto, for example, charges no premium but a technology licensing fee of ~\$6 per acre for its Roundup Ready soybean seeds (a premium of at least 25% over other soybeans). But Monsanto/Dekalb charge a seed price premium of roughly \$8-10 per acre for Bt corn seeds (a 10% premium over conventional seeds). Altogether, in 1997, the premiums charged for GM seeds brought in some \$250 million (Wood and Fairley 1998: 27).

⁵⁸ For a general discussion of contract farming, see Harris and Massey 1968. For a more theoretically informed perspective on the spread of contract farming across sectors and regions, see Watts 1994. For a specific discussion of the emergence and evolution of contracting in the context of grain crops, see Hamilton 1994.

⁵⁹ All purchasers of Roundup Ready soybeans, sign an invoice stating that "If a herbicide containing the same active ingredient as Roundup Ultra herbicide (or one with a similar mode of action) is used over the top of Roundup Ready soybeans, the Grower agrees to use only Roundup branded herbicides" (cited in Fairley 1998: 8).

⁶⁰ To date, Monsanto has brought a number of "seed piracy" enforcement actions against farmers, primarily for saving seeds, signaling the changing balance of power in the agricultural biotechnology complex and the "criminalization" of customary practices under the new regime of proprietary seed technologies (Weiss, 1999).

⁶¹ See Complaint, Picket et al v. Monsanto, filed December 14, 1999 in U.S. District Court for the District of Columbia. Among other things, the complaint charged that "Monsanto's unlawful conduct in aggregating the power to control all aspects of the production of corn and soy appear to be motivated by its desire to control the basic means of production of the global food supply."

⁶² In the first lawsuit, filed on March 27 in US District court in Florence SC, DuPont alleged "a complex scheme of economic coercion through which Monsanto has tried to monopolize cottonseed and herbicide markets." Echoing the earlier charges made by Zeneca, DuPont claimed that Monsanto forced growers into technology licensing agreements that make it "virtually impossible to buy competing brands of glyphosate". In the second lawsuit, filed on March 30 in federal court in Wilmington, DE against Monsanto and its Asgrow subsidiary, DuPont alleged that Monsanto had appropriated trade secrets for producing Roundup Ready soybeans developed in a joint venture between DuPont and Asgrow before Monsanto acquired Asgrow in 1997. As a result, DuPont claims, Monsanto was able to introduce its Roundup Ready soybean two years ahead of schedule, thereby destroying DuPont's own herbicide-resistant soybean. Monsanto dismissed the lawsuits as baseless, suggesting that they were filed in retaliation for a suit Monsanto had recently filed to terminate a 1995 licensing agreement on Roundup Ready seed technology with DuPont subsidiary Pioneer Hi-Bred (Chemical Week 2000b: 9).

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35 U.S.C.A. §100 et seq. (Patent Act)

35 U.S.C. §161 et seq. (Plant Patent Act)

35 U.S.C.A. §200 (Bayh-Dole Act)

7 U.S.C. §2321 et. seq. (Plant Variety Protection Act)

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