AGRICULTURAL BIOTECHNOLOGY AND

NORMATIVE TRANSFORMATION IN ACADEMIC SCIENCE

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ABSTRACT

In 1942, Merton codified the norms of science as consisting of universalism, organized skepticism, disinterestedness, and communalism. Drawing on Etzkowitz's (1989, 1996, et al.) arguments that a normative transformation has been occurring in some fields, this paper examines the impacts of the relatively recent and massive increase in research funding from the private sector on the pace, path, and products of scientific research in agricultural biotechnology. In other words, *what are the impacts of industrial involvement on the subject and the practice of research in agricultural biotechnology?*

Krimsky et al. (1991) and Blumenthal et al. (1986a; 1986b) have shown that academic-industrial ties are notably high in agricultural biotechnology, thereby making it an ideal case for examining the impacts of industrial involvement on the subject and practice of science. Data for this study is thus based on 24 intensive, semi-structured interviews with prominent scientists actively involved in the public and scientific debates surrounding the field. Informants were sought whose situated knowledge could best speak to the question of the impacts of industrial involvement on the scientific ethos. This purposive sample provides a spectrum of perspectives on industry's impact, and is representative of the realm of meanings surround agricultural biotechnology.

This study can serve to verify and elaborate Etzkowitz's arguments that a normative transformation is occurring in science. It is clear from existing research (e.g., Blumenthal et al. 1986a; 1986b) that former boundaries between industry and science are no longer being maintained, and disinterestedness and communalism are increasingly disappearing as elements of the scientific ethos. This study explores the impacts of this transformation.

Recommendations are made for adaptations the university must make in order to sustain a vigorous program of research without sacrificing the scientific ethos to the demands of capital.

KEYWORDS: biotechnology, industry & science, normative transformation, Merton, Robert K.

Put in its most bald form, the question is whether what has come to be called biotechnology will poison the well from which it sprang – academic science.

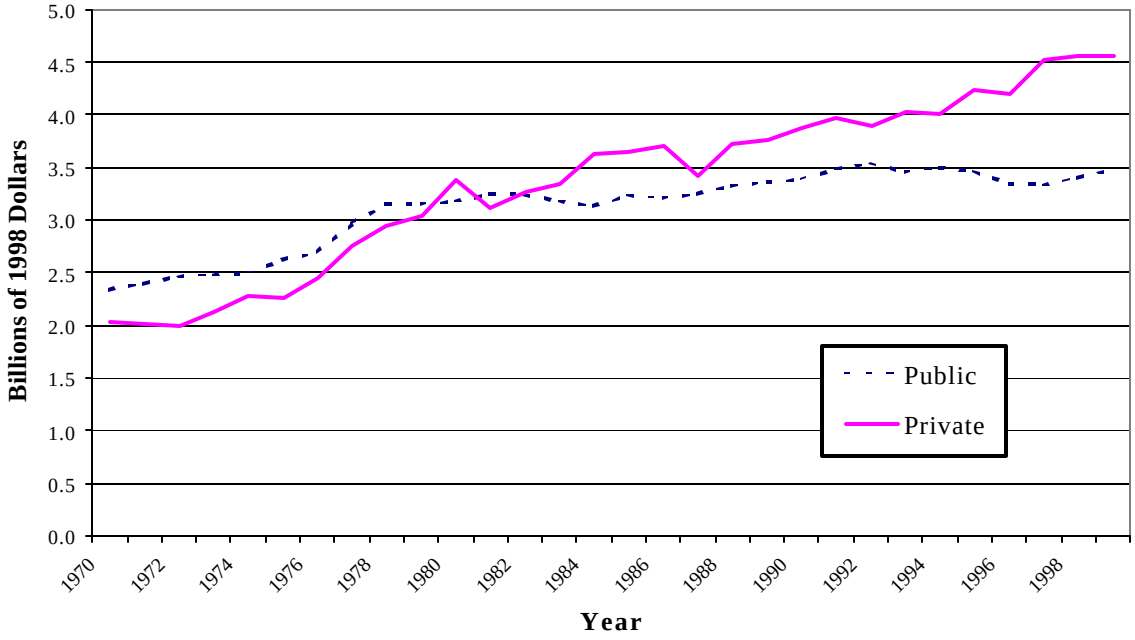
—Clifford Grobstein (1985:55)

Purpose of the Present Research

Scholars have argued that the institution of science has been undergoing a normative transformation in some fields (e.g., Etzkowitz 1989). Drawing on Merton's (1942) pioneering codification of the normative structure of science as involving universalism, organized skepticism, disinterestedness, and communalism, Etzkowitz argues that industry's increasing involvement in academic research has significantly altered these norms. Very little research, however, has explored the *impacts* of this transformation of the scientific ethos on the subject and practice of academic science.

Faulkner et al. (1995), Krimsky et al. (1991), and Blumenthal et al. (1986a; 1986b) have shown that academic-industrial ties are notably high in biotechnology (and especially agricultural biotechnology), thereby making it an ideal case for examining the impacts of industrial involvement on the subject and practice of science. To illustrate the current milieu under which agricultural science is practiced, Figure 1 shows the shift in research monies from predominantly public funds in the 1970s to predominantly private funds from the early 1980s to the present:

Figure 1: Agricultural Research Funding in the Public and Private Sectors, 1970-1999
Source: United States Department of Agriculture, Economic Research Service.



In their 1986 study on the impacts of university-industry research relationships in biotechnology on the university, Blumenthal et al. (1986b) conclude that such relationships are likely to become an enduring phenomenon in academia. Thus, they suggest finding ways to effectively manage these relationships in order to minimize any potential problems. "To accomplish this, we must first increase our understanding of the impact of [university-industry research relationships] on…university values, and the advance of science" (1366).

Despite this recommendation, very little research has been done on the nature of the impacts of industrial involvement on academic science. Indeed, theirs is one of only a handful of studies directly examining this topic at all, and there are virtually no recent studies in this regard. Furthermore, the extent of these relationships and their acceptance within academia has only grown over the past fifteen years. This study focuses the sociological lens on the nature of these impacts by drawing upon the lived experiences of scientists working within segments of academia heavily influenced by industry, namely, those disciplines associated with agricultural biotechnology.

The Normative Structure of Science

Accroding to Merton (1942), the four social norms which constitute the scientific ethos are as follows. First, *universalism* requires that scientists evaluate knowledge claims using "pre-established impersonal criteria," such as current theoretical and methodological assumptions. This is intended to inoculate against biases on the basis of traits such as race, gender, nationality, and institutional affiliation. Second, *organized skepticism* proscribes against dogmatic assertions, urging the suspension of judgment until adequate evidence and argument become available. Third, *disinterestedness* channels the motivations of scientists away from self-interested or politically-interested behavior which would conflict with the institutional goal of science—the extension of certified knowledge. This norm is intended to free scientists from external influences on the direction of their inquiry. And fourth, *communalism* requires that research results be shared. Intellectual property rights are limited to recognition and eponymization, and secrecy is the antithesis of this norm.

In defining science in such a manner, Merton ultimately created a set of criteria for demarcating the boundaries between science and non-science. In other words, any knowledge-producing activity not occupying the territory defended by universalism, organized skepticism, disinterestedness, and communalism is, in Merton's view, definitionally unscientific. This is a necessary assertion because, as Merton states, "[the] authority [of science] can be and is appropriated for interested purposes" (Merton 1973:277).

The "definitional tidiness" (Gieryn 1995:394) inherent in Merton's theory of the normative structure of science

has had its share of critics, who have found fault both with his characterization of the norms and the mechanisms of their operation (Barnes and Dolby 1970; Stehr 1976; Latour and Woolgar 1979; Mulkay 1980; Gilbert and Mulkay 1984; Lynch 1984; Gieryn 1995). Merton's norms are probably best understood as "the official ideology of scientists, but only a crude indicator of their practices" (Chubin 1985:79), and this disjunction has been the basis of much critique. Of particular interest is the criticism that Merton's standardization of the scientific ethos has resulted in an idealized and essentialist view of science (Gieryn 1995), and one which ignores the processes of construction, interpretation, negotiation, and deployment of these norms. That is to say, norms are not merely for discovery and definition by sociologists, but available for interpretation and negotiation by actors in everyday life (Cicourel 1974). Hence, Merton's structural norms are not necessarily deemed invariably relevant or even appropriate within scientific communities. There is an interactional level of interpretation and negotiation which determines how the norm is actualized, if at all.

Normative Transformation in Science

The foregoing critique is impressively astute, but it leaves unaddressed the question of how the norms of science, however they are enacted, may ultimately be transformed. Etzkowitz has examined "the transformation of institutionalized expectations about how academic science is done" (1989:15). At least since the Uniform Federal Patent Policy Acts of 1980, which permitted universities to retain patents on the products of faculty research, disinterestedness and communalism have increasingly fallen casualty to what Etzkowitz terms "entrepreneurial science," i.e., science pursued for profit, with results protected by intellectual property law.

Traditionally, industrial support of academic science has constituted a small percentage of the total. However, inflation—combined with the lack of significant growth in federal research monies—created a stimulus for universities to establish closer relations with industry. This was not a mere happenstance, but a directed policy by the federal government to develop underutilized university research as an economic resource (Reams 1986). From the standpoint of the competitive imperatives of industry, financing university research became central to a strategy of renewal and growth (Goldhor and Lund 1983; Gerson 1987),[1] and the university came to be viewed not only as a source for specialized training and expert advice, but also as a "factor of production" (Etzkowitz 1983:232).

An Overview of Relationships between Industry and Science

While it may be unreasonable to portray those occupying corporate boardrooms as entirely devoid of sensitive

thought, it is important to recognize that their thinking is necessarily constrained by their primary directive of profit maximization (Jackall 1988; Caldart 1983). Simply stated, corporate social actors are constrained by the requirements of their role position. Thus, when agricultural biotechnology firms are channeling billions of dollars into academic science *annually*, it is impossible not to imagine that these definitionally interested parties may be providing some direction, if not dictation, as to the nature of the questions being asked and the answers being advanced. With the growing emergence of these institutional interactions over the past twenty-five years, "the fabric of academic research could be slowly rewoven on industry's loom" (Caldart 1983:30).

While research arrangements between industrial firms and universities are not necessarily entirely novel, "the types of university-industry relationships in biology are more varied, more progressive, more experimental, and more indiscreet than they had been in similar historical circumstances" (Krimsky 1984:3). The existence of large grants and/or contracts between industrial firms and universities is a prime example. These are not eleemosynary contributions, but financial investments. In exchange for research monies, industrial interests gain exclusive licenses for discoveries and patent rights. At the same time, faculty themselves have been entrepreneurially active in setting up their own firms to commercialize the products of their research, as well as serving on the boards of extant firms. As Krimsky et al. (1991:286; cf. Louis et al. 1989) describe the situation, "[faculty] with university and industry affiliation are becoming the rule rather than the exception… Many leaders in the field of molecular biology paved the way to entrepreneurship and serve as role models for younger faculty."

Very significantly, there have been instances at scientific conferences in which a scientist refuses to give details of a technique because of proprietary concerns (Nelkin 1984). As one MIT molecular biologist has noted: "The atmosphere around biology department coffee pots has changed in the last few years" (quoted in Markle and Robin 1985:73). Along this same line of concern, Krimsky et al. (1991) found that 49% of scientists on the National Science Foundation's peer-review list of potential reviewers in biomedical sciences were affiliated with industry. This creates a potential incentive for pilfering innovative ideas to commercial enterprises. What is more, the very perception of such a threat may lead some scientists to bypass the system of peer review altogether, opting instead to directly seek commercial funds for the project. This dynamic can potentially undermine the integrity of the peer-review system. Krimsky (1984) has also suggested that because university-industry research relationships typically involve the most talented, prominent, and influential faculty, they carry the potential to bias the collective judgment

[1] Cf. Buttel 1989 for a challenge to the argument that biotechnology will be fundamental in revitalizing U.S. and

or ethics of scientists in an entire field of research.

Furthermore, and supportive of Ashford's (1983) arguments, Blumenthal et al. (1986b) found that 30% of industrially-sponsored biotechnology researchers reported that the direction of their research was influenced by the likelihood of its commercial application. Very significantly, 70% of industrially-sponsored biotechnology researchers are concerned that commercial involvement will shift attention toward applied research, and 78% of their non-industrially-supported colleagues agreed. These documented tendencies toward greater secrecy and interestedness in industrially-sponsored academic research demand deeper investigation.

Methods

This research is located within the growing literature on the transformation of the normative structure of science (e.g., Etzkowitz 1989), and extends it by analyzing how this normative transformation is perceived and experienced by the practitioners of those disciplines associated with agricultural biotechnology. Agricultural biotechnology provides an ideal instance for examining the impacts of normative transformation, as scholars such as Krimsky et al. (1991) and Blumenthal et al. (1986a; 1986b) have shown that academic-industrial ties are notably high in those fields affiliated with the development of biotechnology.

To pursue these aims, I conducted 24 intensive, semi-structured interviews with scientists actively engaged in the popular and scientific debate over these technologies. Informants were chosen for the specific perspectives and situated knowledge (Smith 1987; 1990; Haraway 1988) they could bring to the study. Because there is significant disagreement among scientists as to the ethics, safety, and desirability of the current development of agricultural biotechnology, I made certain to interview informants from across the spectrum of perspectives. Ultimately, I divided all informants into a heuristic dichotomy: 12 opponents of the current development of agricultural biotechnology and 12 proponents of the current development of agricultural biotechnology.

This "purposive strategy" (Esterberg 2002:93) was supplemented by a snowball sampling technique (Biernacki and Waldorf 1981). Initial informants were identified via articles in mass media periodicals as well as topical Web sites. I asked for further referrals (as well as source citations) from this first level, specifying that I was looking for both opponents and proponents of the current development of agricultural biotechnology.

This overall strategy allowed me to secure data saturation (Glaser and Strauss 1967) as well as ensure both a similarity and dissimilarity of informants (Rubin and Rubin 1995). Saturation became apparent as previous data was

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world economies.

confirmed and information was repeated (Morse 1994). Although some have warned that snowball sampling may yield respondents who are too similar to one another (e.g., Esterberg 2002), the purposive strategy utilized here ensured a broad spectrum of informants.

All informants were academic scientists actively engaged in the popular and scientific debates surrounding agricultural biotechnology. All were affiliated with a university, excepting one who retired and one who, after earning a law degree in addition to a doctorate, accepted a position in a civic organization. Of those affiliated with a university, 17 were full professors, two were associate, and one was an assistant professor. Additionally, one respondent was a postdoctoral fellow, and one worked in a university-funded technology outreach program. Thirteen of the respondents were from public, doctoral/research universities—extensive, one respondent was from a public, doctoral/research universities—intensive, two respondents were from private, non-profit master's colleges and universities I, one was employed in a civic organization, one was retired, and six respondents were from universities abroad not included in the Carnegie Commission's 2000 classification scheme.[2] There were no discernable correlations along any of these axes, with the exception that the international respondents were more likely to oppose the current development of agricultural biotechnology.

Approximately 25% were female, and ages ranged from the 30s to the 60s. There was no discernable correlation between gender and their perspective on this issue. In general, older informants seemed somewhat more likely than the younger to be opponents of the current development of this technology, although there were exceptions to this pattern in both directions. Importantly, none of my informants were against the development of agricultural biotechnology *per se*. Rather, opponents were against the *current* development of the technology.

Respondents self-identified (and these are not discrete categories) as biologists, microbial ecologists, geneticists, molecular biologists, physiologists, evolutionary biologists, biochemists, theoretical physicists,[3] plant pathologists, plant geneticists, plant physiologists, forest biologists, and botanists. Regardless of discipline, what links them together is their participation in the popular and scientific debate over the development of this technology.

Interviews lasted between 60 to 100 minutes. Questions were taken from an interview guide developed to guide the discussion around the intended content areas. Each interview varied as individual informants revealed information that shifted the focus of the discussion. Interviews were conducted over the telephone and arranged via

[2] The 2000 Carnegie Classification database is available at: http://www.carnegiefoundation.org/classification/.

email. With the permission of the informants, all interviews were recorded on audiotape. Informants were informed that all identifying information would be kept confidential and that they were free to decline to answer any question—as well as to end the interview—at any time.

My approach to my data collection and analysis was iterative at all stages (Charmaz 1983), permitting me to refine ideas and develop interpretations from my informants rather than imposing a preexisting theoretical model upon them. Topic areas which focus the presentation of findings emerged as factors from the interviews themselves. I ceased conducting interviews when I was confident that my existing data was adequate due to saturation and confirmation of previously collected data (Esterberg 2002).

After transcribing all 24 interviews, I coded them into multi-layered topic areas using NUD*IST qualitative analysis software (version 4.0). Initially, I sorted the data into broad categories as a method of processual analysis (Charmaz 1983), with each progressive layer being more detailed and specific. This method allowed for maximum flexibility in cross-referencing themes and factors. The first layer of categories was generally based on broad question areas. Further layers accounted for overlap and captured themes which were additionally relevant to other topic areas.

Findings

All respondents, whether proponent or opponent,[4] recognize that the science is in many ways marketplace-driven. However, while scientists on both sides of the debate acknowledge that industry is having an impact on the institutions of science, they differ significantly in the focus of their concerns, the extent of their concern, and their interpretations of the larger situation.

In order to communicate the range of perspectives on these issues and to facilitate a relative ease of comparison, comments by proponents and opponents are organized within the same general outline. In the course of questioning respondents about their impressions of the impact of industry on science, four major topics emerged which will be explored in this paper: (1) ambivalence regarding industrial capital and resources; (2) frustrations regarding the marketing and promotion of the products of agricultural biotechnology; (3) the degree to which profit and commercial concerns are driving the science; (4) problems associated with the proprietary nature of the science and technology. In discussing each factor, the viewpoints of proponents will be presented first, followed by the

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[3] Theoretical physics was his academic training. He wrote on the physics of life processes.
[4] I will use the terms "proponent" and "opponent" as a shorthand means of referring to those supportive and those opposed to the *current* development of plant biotechnology.

viewpoints of opponents.

Ambivalence Regarding Industrial Capital and Resources

According to Etzkowitz (1989), Merton's (1942) description of the traditional scientific ethos has been transforming as a consequence of shifts in federal funding patterns and policy changes regarding intellectual property. Rising costs and sagging sources of federal research funding led universities to seek alternative sources of funding in the form of contractual partnerships with industry. At the same time, pivotal court rulings on the intellectual property protections afforded to the products of genetic recombination and other biotechnologies led industry to become interested in harvesting the biotechnological expertise of academic scientists as a strategy of renewal and growth (Goldhor and Lund 1983; Gerson 1987). The effectiveness of this strategy has been confirmed by Blumenthal et al. (1986a), who found that corporate investment in university research generated 4.2 times as many patent applications, per dollar invested, than company-based research over a five-year period. In short, university-industry research relationships exist precisely because they offer mutual financial benefit to both parties.

Most proponents expressed a surprising degree of ambivalence about the role of industry. That is, while they were enthused about the growth of their field and/or their own research, they were also quite aware of the commercial concerns of their benefactors. Their struggle to come to terms with the relationship between science and industry is evident in the following remarks.[5]

> It's tough. I'm double-minded. As someone who's doing academic research, I've been able to get a lot of the tools, to use the tools for research purposes, and that's good. I have relationships with many of the companies, good working relationships with many of them, and at the same time, right now it's an oligopoly, and that's probably not the healthy situation. As someone said, Monsanto's motto is, if you can't beat 'em, eat 'em. I'm not sure that that's terribly healthy.

Such conflicting sentiments were frequent throughout proponents' interviews, often serving to qualify or disclaim their remarks, and can be seen as demonstrating their own sense of normative conflict. Thus, while they support the current development of the technology, most could not deny that there were very real problems associated with the role of industry in science.

Opponents shared proponents' ambivalence regarding industry's participation in the development of agricultural biotechnology. However, whereas proponents merely expressed uneasiness with industry's influence, opponents were likely to offer a detailed critique. In general, the perspective of opponents seems to be more closely aligned with an idealized view of science as described by Merton (1942), while proponents take a more pragmatic

[5] Unless otherwise noted, multiple excerpts are from different respondents.

view of the situation.

> Industrial involvement has definitely been a mixed blessing…Of course, we need industry. We need the resources of industry to take an idea through to a product that will be of value. But on the other hand, I do know, from experience and from other people, that industry does put undue pressure on academic scientists as to the kind of, it becomes very goal-oriented work. Basic science is often ignored, and things come up which compromise a certain development. They tend to brush these things aside…See, the agenda of industry is very different to the agenda of academia. They have to make discoveries, make products, have patents, and make their profits. In academia, we're motivated by curiosity, basic science investigations, we have to publish, we have to get more grants to survive. So at times we can be pulling in opposite directions…

Frustrations Regarding the Marketing and Promotion of Products

Merton (1973) argued that the normative structure of science patrols the borders of scientific autonomy and provides the conditions necessary for the pursuit of truth. Absent this structure, "[the] authority [of science] can be and is appropriated for interested purposes" (Merton 1973:277).

Of the biotechnology firms studied by Blumenthal et al. (1986a), 52% reported that sponsoring university research enhanced their firm's public image. In the language of Merton, then, by drawing on the authority granted to science—or relying on an increasingly outdated and inaccurate definition—their interested purposes become less evident, and they can claim their activities are "just science." As Kleinman and Kloppenburg (1991:433) point out, this leaves "no legitimate epistemological rationale for the public to be frightened of, or opposed to." For example, witness the words of former Monsanto chairman Louis Fernandez:

> The only thing that will stand in the way of achieving the full potential of our next golden era is that we will be thwarted by a public that doesn't *understand science* or technology and that doesn't trust us to *use science* wisely and with appropriate regard for the concerns of the public we serve…(quoted in Richardson 1985:44; emphases added).

To the extent that industry conducts its business in the name of science, scientists seem to distance themselves from the consequences of these activities. Once again, these frustrations can be understood as expressions of normative tension.

There was consensus among all respondents that industry is exacerbating their own public relations problems by rushing products to market, thereby increasing the likelihood of undesirable outcomes. Notably, while many proponents recognize the irresponsibility of rushing products to market, they are nevertheless quick to normalize the practice or dismiss any food safety issues. Hence, while proponents have well-considered concerns about the current development and deployment of these technologies, their critique often includes an apology for the demands of industry. Such apologies constitute a key difference between themselves and opponents.

> I deal with companies a lot…, I don't see them doing things that are grossly unethical, or even

> unethical at all. I see them…moving to market fast because they want to get market share, and maybe they could've done a little more science, that would've been nice, but I don't see it being grave problems [sic]. Of course, I get some money from companies. I've got a conflict of interest there. But I can tell you, I wouldn't take money if I thought they were really doing something that offended my sense of ecological decency…

On the other hand, there were some proponents who were quite frank about the requirements of industry. The following excerpt paints a relatively unapologetic portrait of industry's position, and also alludes to the financial liabilities which make such haste inevitable. The following remarks indicate not only that companies are competing with one another for market share, but that they are also desperate to recoup some portion of their immense investments in the technologies.

> There's been a rush to market way ahead of time, especially here in the South with the cotton…All of a sudden, here they are, and half the South's planted in cotton, and it's coming down in virus diseases. Again, it's just a combination of shoddy breeding with rush to market...I think it has to do with the way financing is done in the United States in this day and age. They have spent. The investments have been really, really heavy, you know, upwards of a billion dollars. And if you want to keep your stock price going, you've got to have some recovery on that.

Essentially, then, proponents find industry culpable for the mismanagement of the products of their research. The last sentence of the excerpt above highlights the separate and even opposite agendas of science and industry, and illustrates that the frustrations of proponents often stem from the *interestedness* of industry.

This debt-driven approach to science seems to create an atmosphere of desperation in the promotion of the products of agricultural biotechnology. This is evident in the ways those corporations heavily invested in the technology approached the marketing of their products. This was a very common frustration expressed by proponents. In attempting to manipulate the public, political, and commercial environment, these proponents feel that industry has only succeeded in helping to discredit the technology. This is again reflective of the gulf between the scientific and the industrial approach to the field of agricultural biotechnology. That is, scientists are enthused that their disciplines have been the recipient of corporate largess, but frustrated by actions taken by industry in the name of the scientific disciplines they sponsor. Consequently, proponents frequently condemn the more egregious actions of industry in the interest of salvaging the scientific foundations of the technology. These frustrations can be understood as expressions of normative tension, and express a sense of the loss of control over the utilization and public presentation of their research.

> I think that there had been years of investment and here was now a chance to get a return on that investment…And then I think Monsanto took way too heavy-handed an approach in trying to drive their products into the marketplace in Europe, and it just ticked the Europeans off, including very thoughtful people, people that I know from my own profession that said, you can't believe how they treated us. I think Monsanto has to take full responsibility for that.

Given such remarks, it almost seems unlikely that these scientists would nonetheless identify themselves as proponents. This may be interpreted as a means of balancing the contradictory agendas of science and industry. In other words, a major criticism that has emerged from proponents is that although agricultural biotechnology is based on "good science," the involvement of industry has resulted in a reckless and bullying approach to the introduction of the technology. My impression—intended as analysis and not dismissal—is that proponents wish to maintain both the industry-driven pace of their field as well as the respect traditionally accorded to scientists, and so they distance themselves from the interested and hasty activities of industry.

In the absence of the pressures created by competition and the shareholder imperative, it is unlikely that agricultural biotechnology would have been perceived by the European public as having been force-fed. In other words, if agricultural biotechnology had emerged only from publicly-funded scientific institutions, its introduction, however much slower, would not have been premised on such market-driven urgency. In the current context, proponents are offering accounts and engaging in role distancing, and this can be seen as evidence of their own normative conflict.

In considering the impact of industry on science, proponents were quick to point out its failures in terms of the introduction of the products of agricultural biotechnology to the public. This, along with their frustrations about proprietary science, constituted the main themes of proponents' critiques of industrial involvement in agricultural biotechnology. While opponents certainly shared these concerns as well, they had much less to say in this regard specifically—perhaps because they were not trying to reconcile contradictory normative structures. Nonetheless, opponents did articulate frustrations with industry's hasty approach to the release of GMF's. The major difference is that opponents offered no serious apology for the commercial demands of industry. Proponents perceived the issue in terms of a rash and clumsy approach to public relations by an industry increasingly desperate to recoup their investments. Opponents, on the other hand, were more apt to view the situation as the result of cold calculation by an industry intent on controlling the intellectual property underlying the world's food supply. Indeed, the portrait of industry offered by the following opponents is exceptionally disturbing.

> Industry's gambit is clearly, or was, I don't know whether it still is, to actually have the whole thing sewn up, on the market, no choice, and that's the way it's going to be guys, and that's a bit tough but sorry. I think Monsanto, if you sort of sent some trainee advertising agent to go and design an appalling campaign, the worst you can possibly think of, they'd've done well to match that.

In sum, it is quite clear that regardless of a respondent's point-of-view, all recognized that industrial

involvement in the development of agricultural biotechnology has come with costs to the practice of science.

Market-driven Science

In exploring the potential consequences created by the commodification of seeds, Buttel and Belsky (1987) and Busch et al. (1991) cautioned that a research agenda determined primarily by the interests of private capital risks leaving many locally useful crops and potentially serious agricultural problems uninvestigated (cf. Heisey et al. 2001). As well, because agricultural biotechnology corporations have also systematically bought most seed companies around the world,[6] certain crops could simply be—and are simply being—abandoned (RAFI 17 July 2000). The following respondent speaks of this problem on a general level:

> There's been a sheer arrogance of preventing their technology—this reflects all the biotech companies—from going to help. You know, there's certain crops that they're never going to make a profit on. The market's not big enough, the crop's not important enough, the trait's not important enough, so that these companies are never going to touch these particular crops. Nevertheless, these are crops that would be very useful to local communities or farmers on the regional level.

Markle and Robin (1985) argued that commercial application could become the primary or sole criterion of problem selection in genetic science, thus altering the agenda and practice of science and "reconstructing" genetic science on the basis of commercial requirements. "[The] *business* of biotechnology will promote, and probably co-opt, and thus alter the *science* of molecular biology (Markle and Robin 1985:77; emphasis original). Thus, while corporations and the academic scientists they are funding "go to great lengths to stress the intellectually driven nature of the projects being funded" (Etzkowitz and Webster 1998:61), this ignores the fact that this research trajectory is proceeding at the expense of other less-profitable directions.

In this particular theme as well, opponents had less to say than proponents. Once again, the perception among most opponents I interviewed is that industry is having a negative impact on the institutions and ideals of science. They were less likely than proponents to discuss the specific problems that emerge from the involvement of industry as issues to be dealt with than they were to discuss them as evidence that industry is corrupting the goals of science and mishandling the technology as a means of market manipulation.

What is more, the following respondent describes how governing institutions, who might have functioned to balance the contradictory impulses of science and industry, may have ceded its role to the requirements of capital as well.

> Shapiro[7] said a couple of years ago that in ten years time everything will be genetically-modified. If you add all that up on a case-by-case basis of looking at [risk assessment], that's a lot of dollars. That would certainly cut into the profits of this industry. And they are not very willing because most of the governments, including our own here in Britain, have invested heavily (our pension funds and all that) into biotech shares, therefore it is not in their interest either to cast any doubts on it. But I just still have to say that I'm a scientist, I look at the facts and make up my own mind. Like or dislike doesn't come into it, I'm afraid.

This financial path dependency limits the practical options that a scientific or government institution actually has. To the extent that economic well-being is dependent on the success of these technologies, the likelihood of discouraging the dissenting voice increases, and this constitutes a major theme among opponents.

Proprietary Science

While the ideals of science as described by Merton (1942) are certainly limited by professional competition, personal ambition, epistemological cliques, and other human characteristics, they nonetheless serve to protect against practices such as the restriction of information flow *as a general practice*, thereby maintaining "innovative vigor" (Grobstein 1985:56). The business worldview, on the other hand, encourages the restriction of information, using trade secrets, or the restriction of its use with patents, as strategies for protecting investments.

The norm of corporate secrecy is overwhelming the norm of scientific cooperation. As already mentioned, Nelkin (1984) reported on instances at scientific conferences wherein scientists refused to give details of their techniques due to proprietary concerns. Additionally, Blumenthal et al. (1986b) found that 41% of the biotechnological firms reported that their funding of university research had resulted in at least one trade secret. At the same time, industrially-sponsored researchers were four times as likely as their non-industrially-sponsored colleagues to report that their research had resulted in trade secrets. Furthermore, 44% of industrially-sponsored researchers reported that university-industry research relationships risked undermining intellectual exchange and cooperation, while 68% of non-industrially-sponsored colleagues agreed.

Intellectual property law seeks to motivate innovation in technique by guaranteeing rewards. With agricultural biotechnology, however, the notion of "private knowledge" undermines the practical utility of the technology, not to mention a core component of the scientific ethos. We have seen how a proprietary technology directed only by commercial concerns can leave many areas of potentially important research entirely unexplored. In this section, we will see how such a proprietary science can in many ways act as an ironic hindrance to the pace of scientific

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[6] In 2000, the top ten seed companies controlled approximately 31% of the worldwide commercial seed market (RAFI 2000). Limited to vegetable seeds only, just five companies control 75% of the global market (RAFI 17 July 2000).

innovation.

The proprietary nature of the technology was the most common frustration cited by proponents. The following proponent, however, sees no alternative. As will be shown shortly, this is a major point of difference in the nature of concerns cited by opponents. They perceive alternatives, which are generally perceived as quixotic by proponents.

> [If] a company isn't in the position of being able to reap the returns on the massive, and it is massive, investment that they make in the science, then it's never going to be done, so it's never going to get out there. So to me, to the question is really what is the cost of not doing this, or what is the cost of making it such that nobody will do this type of research? It would be wonderful, gosh, it would be wonderful if it could all be free and available, but the reality of the market economy is that for these industries to survive, they are going to have to be able to pay their researchers and pay their investors.

It is clear from examining the above excerpt that at least for this respondent, Etzkowitz's (1989) normative transformation is entirely complete – proprietary science is taken for granted. Nelkin (1984:11) warned almost twenty years ago that "the commercialization of molecular biology may be eroding the pattern of open communication and exchange of information essential in this field." This prediction has been realized. Proprietary science has become the norm.

Seeing no alternative to the given, the content of proponents' criticisms often becomes little more than highbrow complaining. Echoing an earlier theme, they are enthused that their disciplines have become so well funded, yet they find the *un*sharing of scientific information to be a considerable obstacle to technological advancement.

> [It's] very, very frustrating for someone like me to try to study the risks when it's all confidential business information, and these companies don't, they're not very open. It's difficult to see what kind of information they're submitting to USDA when they try to get their crops approved and things like that. And then from the point of view of Third World countries, a lot of these very useful genes are tied up in patents, all these multiple patents that have to be approved.

Because the "enabling technologies" are proprietary as well, it threatens to increase the gap between private and public sector research. In explaining the approach taken to research by the biotech industry (which is not necessarily typical of all industries), the following respondent describes how this greatly increases the obstacles to effective public sector research. This respondent also proposes a reasonable alternative to the current situation.

> You develop technologies, you use those technologies, you think what you want to do, you create something, but every one of those steps along the way is protected. It makes it almost impossible for anybody in the public sector to start from A and go all the way to Z and create a product…And so, what I would like to see is I would like to see enabling technologies all put in a basket in the middle of the room, and when you need one of those to create your new plant or new food or whatever, you go to the basket and you pick out what you need and you go back to the lab and you

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[7] Robert Shapiro was the former CEO of Monsanto.

> do what you do, and when you get your product, then you protect it. You don't protect all the things in the basket. That's what I would like to see as the way we move forward…

At the most straightforward level, opponents simply expressed discomfort with the premise behind an agricultural biotechnology that is more or less owned and directed by industrial concerns. In contrast to proponents, they are unable to convince themselves that they are still working for people rather than for profits.

> I guess about thirty years ago, a good part of the funding in my area came from governments, and it was research done for the common good. I guess in Canada a good example could be the development of the crop canola, which was developed for prairie farmers so they'd have an alternative crop to wheat, so that if wheat went bust they'd still have an income. And we spent about thirty years to develop canola, to get rid of some of the poisons which are in rape, which is the wild relative…Monsanto took our crop and put in a gene so that the canola is resistant to Roundup…So we now have Roundup-Ready canola, which the farmers have to pay to use the patent, and have to make promises about not saving the seed and planting but going back to the company and buying it every year. So instead of something for the common good, it's something for the profit of the company.

On the other hand, opponents shared an awareness with most proponents that proprietary science hinders the utilization and advancement of these technologies. The primary point of difference here is that whereas proponents see this as cause for frustration, most opponents see this as cause for resistance. It also seems that the perceived mechanism of hindrance for proponents is mainly the problems associated with intellectual property law, whereas for opponents it is mainly the damming of the flow of scientific information and the consequent stagnation of knowledge.

> Forget about genetic engineering and just look at what's going on in medicine and the increasing ties of industry with medicine. There's some scientists who are being sued because they were testing a product for some company and they found that it was ineffective and they published that and the company is suing them. That sort of thing is happening… {The} corporations were lobbying that this information was proprietary. Even failed experiments would tell too much about what's going on. They've really been pushing for industrial confidentiality, whether it's non-genetically-engineered pharmaceuticals or whether it's genetic engineering.

Opponents are becoming alarmed, in other words, because those norms which characterize the scientific approach are being undermined by their close associations with industry. Without a free exchange of information, individual scientists are prevented from acting from a point which encompasses the available knowledge about a given object of inquiry. The consequences of this run deep, for as Longino (1990:90-1) notes, "[such] privatization of knowledge cannot help but influence the development of knowledge if only by insulating mainstream investigation from discoveries in classified and 'privately held' inquiry." Intellectual property, proprietary knowledge, private science, these are terms that run contrary to what these respondents had hitherto recognized as science.

> I think in general it's had a negative impact, a profoundly negative impact on the speed and accomplishment in this field because, in general, information has become so much more

> proprietary. At the time I was a student and throughout most of my professional career, why, we exchanged strains of molecules and information freely, and it was just expected…Beginning when the possibilities of patents became acceptable, then this whole process stopped. Publication became much more proprietary both within the university and within the companies that it cropped up...The emphasis of research became much more attuned to what was commercially viable in the short run. From a technical point of view, that did, I think, stymie information flow a great deal. It did really stymie both information flow and the development of ideas...

The industrial approach views knowledge in terms of profitability. To the extent that the scientific approach does not threaten this directive, there is no contradiction. However, in pursuing truth, science requires all the information available, and so is inherently contradictory. As well, due to the immensity of industrial investment, financial pressures have been created which encourage the creation and marketing of products of agricultural biotechnology as soon as technically feasible. As already discussed, proponents and opponents recognize this.

Significantly, none of the opponents interviewed were necessarily against the technology itself. Rather, they were against the manner in which the technology was being handled. In this new-fashioned system of proprietary knowledge, opponents argue that the technology has stagnated at a very early level of development. That is, while its rapid development thus far may be attributed to the involvement of industry, so may its relative lack of development. The implications of this dynamic are difficult to overstate. As Blumenthal et al. (1986a) found in their survey of biotechnology firms, the primary reason companies invest in university-based research is to keep current with significant new research. However, the irony of increased industrial involvement is that the undirected, basic research that companies wish to keep abreast of suffocates in the presence of immense industrial investment. This is congruent with McNally and Wheale's (1998) arguments that patenting and the consequent monopolization of particular fields of biotechnological invention ultimately creates disincentives to further R&D investment. Innovation thus slows, and the technology stagnates. The following respondent discusses this dynamic:

> [We] have got a very imprecise and extremely unpredictable technology whose effects and health effects and environmental effects we cannot actually predict. And this technology…has inhibited scientific inquiry into other more precise methods of genetic modification…We have an imprecise technology, and because it was relatively successful, and because it's been patented, therefore it does inhibit the development of further, more precise genetic modification methods…and there are other methods of trying to do it, but there has been no money forthcoming for it…So, this is the main point. I'm not on religious ground or any other ground. What I do hate is poor science, and this is poor science. I resent that everybody tells me that I'm a Luddite because I ask for more science and not less. I am not in the pay of those companies who are likely to benefit from this, or who are already benefiting from this business. They should have done a proper job. They have not done it. In their huge rush towards who will be the first to patent and get it out on the market, they just cut corners everywhere.

Summary and Conclusion

That powerful economic forces are behind the apparent embrace of agricultural biotechnology by science is

seemingly undeniable. And yet for some scientists, such an assertion is heretical to the spirit of scientific inquiry. After all, it is a "constitutive value" (Longino 1990) of science to represent the objective—and thus supra-contextual—stance. To suggest that the path of scientific progress has been colonized by industry and is thereby something other than the straightforward march of a value-free, disinterested science violates this laudable ideal.

Yet, this is precisely what this paper demonstrates. This analysis has demonstrated that industrial interests—interests which are by definition profit-driven—are having a significant impact not only on the directions of genetic science, but also on the content of its debates, the pace of its research, and the continued credibility of its scientists. **T**his paper has shown that industrial involvement in those disciplines related to the development of these technologies has radically transformed the normative milieu of these knowledge-producing activities. At issue is the impacts of the erosion of two components of Merton's (1942) normative structure of science: disinterestedness and communalism.

Disinterestedness

The perceived credibility of scientists and their institutions is closely linked to their impartiality, or *disinterestedness*. Without a normative structure encouraging this, the legitimacy of scientific assertions is increasingly questionable. Most respondents saw industrial involvement as a "double-edged sword," and the attitude of most toward industry was ambivalent at best. Significantly, elements of the normative structure of industry can be seen as replacing disinterestedness as one element of the normative structure of science.

Proponents cited many examples of industry rushing products to market. Their frustrations stem from an industrial definition of the situation overwhelming the scientific. Proponents clearly enjoy their research, and are confident in the health and environmental safety of GMF's, and yet they recognize the irresponsibility of industry's approach to the release of these products. This frustration stems directly from the *interestedness* of industry. Industrial investments have been incredibly immense, and the imperatives of competition and profit create industry's normative system.

What is more, many proponents expressed astonishment at industry's arrogance toward their market. This too stems from a frustration with the normative structure of industry (or a frustration with being associated with such an approach). The agricultural biotechnology industry, after all, frequently presents itself as "just science" rather than "just profiteering." Scientists, meanwhile, have lost control over the utilization and the public presentation of the products of their research. Consequently, such industrial colonization of science risks undermining the perceived

legitimacy of scientists themselves.

Proponents as well as opponents discussed their discomfort with and the consequences of commercial considerations stimulating the development of these technologies. Both the pace and the direction of agricultural biotechnological development are significantly influenced by financial arguments. Hence, decisions about marketing and/or commercialization potential are taking precedence over decisions regarding health safety, environmental safety, and whether the technology and its products even serves the larger public need and/or good.

Opponents also discussed the irony of corporate involvement in the development of these technologies. Whereas commercial interests are rushing the early products of agricultural biotechnology to market in their attempts to keep and/or control market shares, investment in more precise, refined methods of genetic modification have not been forthcoming. Thus, while the development of the technology thus far could not have occurred without industrial involvement, it now appears that industry is merely relying on the investments that it has made and the intellectual property that it controls. According to some opponents, the technology is at risk of stagnating at a relatively early level of development. This dynamic underlines the normative contradictions between science and industry.

Communalism

The norms of industry demand proprietary rights over knowledge, and hence there is an inherent variance with the norms of science. Thus, the second of Merton's (1942) norms of science undergoing transformation (Etzkowitz 1989) is *communalism*, the uninhibited sharing of information between scientists. Increasingly, proprietary concerns are overriding communalism in those disciplines related to the development of agricultural biotechnology.

The norm of communalism serves the purpose of maintaining "innovative vigor" (Grobstein 1985:56) in a given field of study. On the other hand, intellectual property law attempts to motivate innovation by guaranteeing rewards to the innovator. Accordingly, there is an immediate contradiction between these two approaches to innovation. According to most proponents, applying the intellectual property model to agricultural biotechnology has resulted in an undermining of the practical utilization of the technology by tying up products as well as techniques in multiple layers of patent law. Opponents see also that it undermines a core component of the traditional scientific ethos, and that in many ways intellectual property acts as an ironic hindrance to the pace of scientific innovation in these fields.

Specifically, without the free exchange of information, communalism is undermined and researchers are unable

to access either all available knowledge on a given research question, or unable to access patented biotechnological techniques—"enabling technologies"—necessary for performing certain procedures. Proponents see this as a hindrance to the utilization of the technology and a cause for considerable frustration. Notably, however, they dismiss any possibility of alternatives. This demonstrates that norms of communalism are already obsolete in their minds, and that the transformation of the normative structure of science is all but complete. As discussed above, opponents primarily see intellectual property as a hindrance to innovation in the technology, and are uncomfortable practicing science for proprietary purposes rather than the common good. Both recognize that this dynamic threatens to increase the gap between public and private sector research.

Very significantly, all opponents emphasized that they were not against the technology itself. Rather, they were against the commercial premises of research, the commerce-begotten secrecy, haste, market-manipulation, and stagnation. Even a conservative reading of this data grounded only in the perspective of proponents demonstrates that science is not operating as a social force independent of the requirements and the culture of industry. These findings, along with existing research (see e.g., Etzkowitz 1983; 1989; 1996; Blumenthal et. al. 1986a; 1986b; Krimsky 1984; 1988; 1991; Krimsky et. al. 1991; Webster and Packer 1996), make it undeniable that industry is driving some—if not most—of the research in agricultural biotechnology. However, and despite the near-complete dismissal of opponents by proponents, there is no reason not to admit the perspective of opponents as having situated knowledge which speaks very well to the question at hand. Indeed, opponents' perspectives more closely reflects the findings of existing sociological research on normative transformation within science.

Discussion

It is clear that in order to preserve the authenticity of science, science itself must recognize its own embeddedness in the social world. It is its failure to do so that has left science open to colonization by interested social forces in the first place. Assumed notions of value-freedom and objectivity create a cultural space as powerful as religion once was (and often still is) in its ability to dictate reality (Noble 1997). Merton (1943) recognized the normative structure necessary for the extension of certified knowledge. That this structure has been shifting (Etzkowitz 1989) is indisputable. However, this need not be the end of the story. Science can coexist with transnational industries, fascist regimes, fundamentalist religions, or any other social institution, but the true aspirations of science will persist only to the extent that it recognizes the influences of its own surrounding social context. As Longino (1990) has indicated, it may well be the case that scientific neutrality and autonomy are

approached precisely to the extent that the influence of political, social, and economic conditions are given proper recognition. In other words, no scientific assertion should be made without footnoting the social context, perhaps even highlighting it.[8]

I agree with Kloppenburg (1988:279) when he states that "[we] must not allow our options to be foreclosed by ceding to capital the exclusive power to determine how biotechnology is developed and defined." However, government officials and university administrators can only act on the basis of information, and information on the dynamics unfolding between industry and science are rather lacking within the literature. This research offers an in-depth understanding of problems emergent from university-industry research relationships. Moreover, and reiterating Blumenthal's et al. (1986b) suggestion, research in this area must continue to develop in order to provide the information necessary to effectively manage university-industry research relationships.

University administrations have already established committees to define rules of conduct in university-industry relationships in accordance with institutional objectives (Etzkowitz 1989). These committees should recognize the value of the university's intellectual culture vis-à-vis industry, and act to minimize industry's undue influence on the direction of science while maximizing the undeniable benefits. This perspective can also be seen as potentially valuable to corporate firms looking to invest in university research. After all, Blumenthal's et al. (1986b) pioneering survey found that industry-supported university research generated 4.2 times as many patent applications, per dollar invested, than company-based research over a five-year period. They also found that the primary reason companies invest their research and development dollars in university-based research, and not merely company-based research, is that it helps them keep current with significant new research. Ironically then, the more that university-based science is driven by interestedness with proprietary and unshared research results, the less effective it will be in generating the cutting-edge research for industry to develop into products.

In conclusion, this research contributes to a growing body of evidence demonstrating the importance of retaining traditional normative structures of science. This is an imperative not only for science and the pursuit of truth, but also for those industries who rely upon the innovation that these structures create.

[8] Notably, this point of view may be gaining acceptance. A dozen of the world's most prominent medical journals recently announced that they would reject manuscripts submitted by authors who did not have control of either the data they used in their studies or the decision to publish the results *(NEA Higher Education Advocate* 2001).

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