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Crops and Controversy: Industry's Role in the GMO Debate

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Introduction

Industry funding for research has become part of the basic structure of the scientific enterprise. The Edison Illuminating Company began providing funding for technological research and development as early as the 1880s, and General Electric sponsored science and technology research in the 1920s (McGuire and Granovetter 1993). Partnerships between industry and the federal government were significant during the two world wars (Rosenberg and Nelson 1994). This was accompanied by huge surges in federal research dollars at the onset of the cold war and after the launch of the Soviet Union's satellite Sputnik, the world's first man-made satellite (Bybee, Rodger, and Fuchs 2011). During the late 1970s, concerns about the decline of innovation in the United States and economic stagnation led to a series of policy chances that encouraged entrepreneurship in academic science (Berman 2011). Federal funding for scientific research and development provided by the U.S. government has fallen by nearly 13% since its peak in 2011, while industry funding has continued to increase (NSF 2016) (Figure 1). Both government and industry funding provide important resources; however, the two types of funding are not interchangeable. Industry sponsorship is typically directed toward applied research leading to the development of new technologies while for the most part the government supports basic research with the aim of expanding scientific knowledge (Berman 2011).

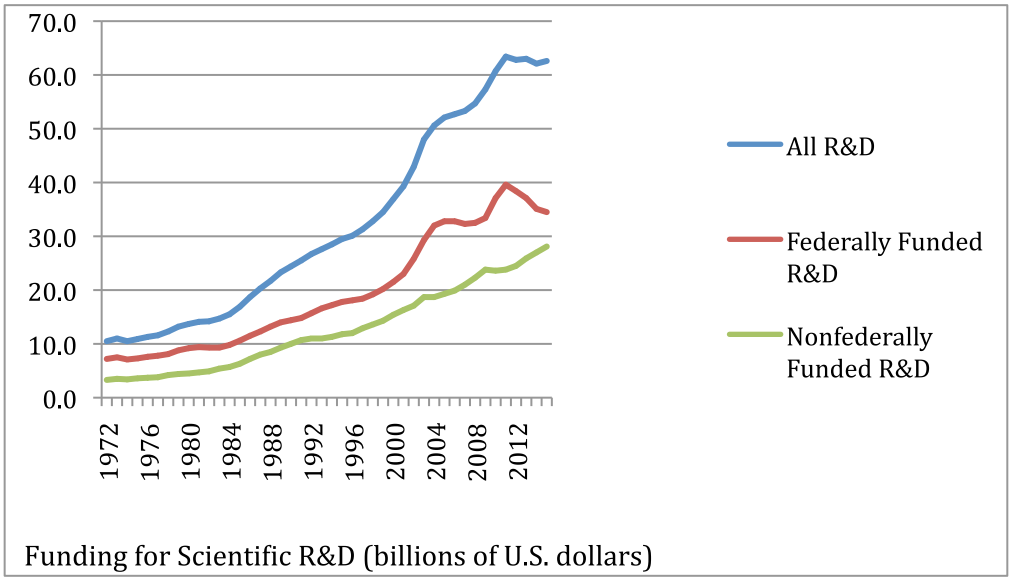

Figure 1. Funding for Scientific R&D 1970 - 2015 (National Science Foundation 2016)

Industry sponsorship for research provides a variety of benefits for both scientists and private companies. Advanced scientific research is often extremely expensive, and the insufficiency of available governmental funding sources limits the possibility of conducting certain types of studies (Bickford 2004). As a result of academia-industry partnerships, scientists receive resources and a source of funding, and corporations benefit from the expertise of skilled researchers who have access to university laboratories (Campbell et al. 2005; DuVal 2005).

Nevertheless, certain scholars are concerned that conflicts of interest due to collaboration between scientists and corporations may compromise the integrity of academic research (Bickford 2004; Campbell et al. 2005; DuVal 2005). In the case of university research, the risks of conflicts of interest may not be readily apparent until corporate interests begin to direct research priorities. In a 2003 interview, Derek Bok, former president of Harvard University, expressed his concern that private interests can slowly and subtly begin to impact scholarship;

“at the outset, profits to be made seem all too tangible, while the risks appear to be manageable and slight [...] The problems come so gradually and silently that their link to commercialization may not even be perceived” (Lotter 2008: 52). As conflicts of interest have become apparent, some scholars are becoming frustrated with private influence over university research priorities (Bressler 2009; Krimsky 2015; Lotter 2008; Monbiot 2003; Peekhaus 2010).

Agricultural biotechnology research provides an example of a sector that has been significantly influenced by corporate sponsorship, with private funding for agricultural research surpassing public funding in 2010 (figure 2). The development of genetically modified crops (also called GM crops, genetically modified organisms, or GMOs for short) has become a highly contested issue. New genetic modification technologies offer a variety of advantages. Nevertheless, some scientists argue that the safety testing conducted thus far does not provide enough information and worry about possible health and ecological risks (Bawa and Anilakumar, 2012; Clark, 2006; Hilbeck et al., 2015). Disagreements regarding GMOs have extremely stakes for the companies invested in creating and marketing genetically modified seeds.

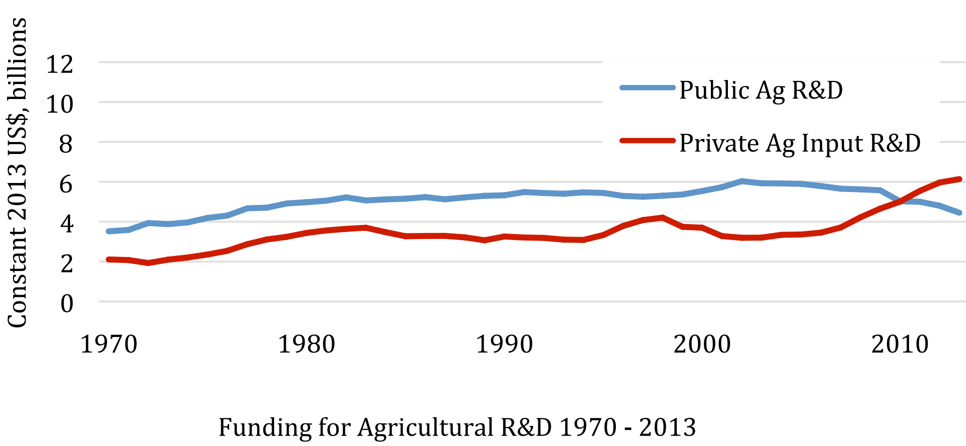

Figure 2. Funding for Agricultural R&D (Clancy, Fuglie, and Hasey 2016)

As the international controversy regarding the use of genetically modified crops has unfolded, the very companies responsible for commercializing genetically modified crops have gained substantial influence in the resulting scientific and political debates (Lotter, 2009; Myhr & Traavik, 2003; Peekhaus, 2010). Through an examination of the prevalence of conflicts of interest in scientific studies regarding the safety of GMO crops and an analysis of funding sources for university agricultural research, I investigate the impact of industry sponsorship on the integrity of GMO crop research. Using case studies, I explore the complexities of the ongoing debates between agribusiness-affiliated scientists and non-affiliated scientists, some of who express concerns about the safety of genetically modified crops.

Chapter 1: Background on the Green Revolution and Genetically Modified Crops

To understand the intense polarization regarding the use of genetically modified crops it is helpful to review the historical context that led to their widespread use. In the 1940s, a plant scientist named Norman Borlaug began manually crossbreeding Mexican wheat plants to develop high-yield wheat with the hopes of finding solutions that would alleviate global malnutrition (Evenson and Gollin 2013). Borlaug was able to produce new varieties of plants that were more resistant to diseases and could tolerate large quantities of fertilizer (Staley 2009). By incorporating dwarfing genes into grain crops he was able to develop shorter and stiffer varieties of plants that devoted more energy to grain and less energy to straw or leaf material (Hesser 2006). These plants responded more favorably to fertilizers than did traditional varieties of grain (Evenson and Gollin 2003). Borlaug also worked in India and Pakistan where he introduced high-yielding varieties of rice and grain (Staley 2009). High yield varieties were eventually introduced in Egypt, Tunisia, Syria, Iran, Libya, Jordan, Lebanon, Turkey, Iraq, Afghanistan, Algeria, and Saudi Arabia (Hesser 2006). In many areas, particularly those with adequate rainfall or access to irrigation, these new varieties of crops yielded significantly more rice and grain than conventional crop varieties (Staley 2009).

The implementation of high yield crops, new crop varieties, increased fertilizer and chemical pesticide usage, and supporting policies is commonly referred to as the Green Revolution, and Norman Borlaug is often called the "father of the Green Revolution" (Patel 2013). Borlaug's agricultural innovations and associated policies resulted in a significant increase in food production, especially in Southeast Asia and in many regions of Latin America (Bazuin et al. 2011). High yield crops and increased fertilizer and pesticide inputs accounted for roughly 90% of the increase in global food production in the 1960s and approximately 70% of the increase in global food production in the 1970s (Bazuin et al. 2011). Mexico and India had previously been food insufficient; however, as a result of higher yielding crops, both countries became self-sufficient in producing cereal grains, leading to significant reductions in undernutrition (Patel 2013).

Despite the clear benefits of the Green Revolution, it was not without drawbacks. Increasing crop yields often leads to soil degradation and increased soil salinity, which may decrease long-term productivity (Bazuin et al. 2011). In order to increase crop yields, chemical fertilizers replaced animal manure or mineral fertilizer resulting in chemical pollution (Evenson and Gollin 2003). Many of the pesticides used to improve crop yields are persistent in the environment and have detrimental environmental and human health impacts (Evenson and Gollin 2003). Scholars also note that in a variety of cases, the poorest citizens remained unable to afford food despite significantly increased yields (Altieri 2004; George 1990; Rosset, Collins, and Lappe 2000). The Green Revolution did little to redistribute purchasing power, and immense economic inequities continue to prevent the most vulnerable groups from accessing food (Altieri 2004; Bazuin et al. 2011; George 1990; Rosset, Collins, and Lappe 2000).

Nevertheless, many scholars consider the Green Revolution to be among the greatest humanitarian accomplishments of the Twentieth Century and praise Borlaug's devotion to working to feed a growing population (Bazuin et al. 2011; Evenson and Gollin 2003; Staley 2009). Those who knew Borlaug considered him to be a relentlessly hardworking, humble, selfless, and practical scientist who recognized the political importance of measures to alleviate hunger and poverty (Staley 2009). Borlaug won the Nobel Peace Prize in 1970, and some scholars estimate that his work prevented approximately one billion malnutrition related deaths (Bazuin et al. 2011; Staley 2009). Borlaug argued that we would not be able to feed the global population "unless farmers across the world have access to current high-yielding crop production methods as well as new biotechnological breakthroughs that can increase the yields, dependability, and nutritional quality of our basic food crops" (Borlaug 2000: 4).

As a result of the Green Revolution, there was greater interest in and awareness of the possibility of modifying crops in order to increase yields and improve agricultural efficiency. In 1973, scientists at Stanford University and the University of California San Francisco created the first genetically engineered organism (Cohen et al. 1973). These scientists developed a method that allowed a gene to be cut from one organism and transferred into another (Rangel 2015). They successfully transferred a gene for antibiotic resistance from one strain of bacteria to another strain of bacteria and found that the second strain of bacteria also became antibiotic resistant (Cohen et al. 1973). Scientists continued to develop a variety of new applications for gene transfer; however, there was limited economic motivation associated with creating genetically modified organisms (Rangel 2015).

In 1980, the United States Supreme Court ruled five to four that General Electric should be allowed to patent genetically engineered bacteria that could break down crude oil in order to mitigate oil spills (Rangel 2015). As a result of this court ruling, corporations were able to gain ownership rights over GMOs, and companies had a new financial incentive to develop genetically modified organisms (Yang and Chen 2015). Just two years after the court ruling, scientists working at Monsanto, one of the world's largest agriculture and chemical companies, became the first to genetically modify a plant cell (Rangel 2015). In 1996, the United States Department of Agriculture approved the first genetically modified crops for commercial production (Yang and Chen 2015).

Since the 1996 approval, the use of genetically modified crops in the United States has increased rapidly. As of 2016, 94% of soybeans grown in the country are genetically modified to be more herbicide tolerant, 79% of corn is modified to include genes for pest resistance, and 89% of corn is modified to be herbicide tolerant (Figure 3) (USDA 2016). Crops containing genes for herbicide tolerance are referred to as HT varieties, and crops that contain genes from the *Bacillus thuringiensis* bacteria, which is poisonous to certain insects, are called Bt varieties. A single crop can be modified to contain genes for both pest resistance and herbicide tolerance. In the last twenty years, GMO corn and soybeans in the United States have almost completely replaced conventional varieties (USDA 2016).

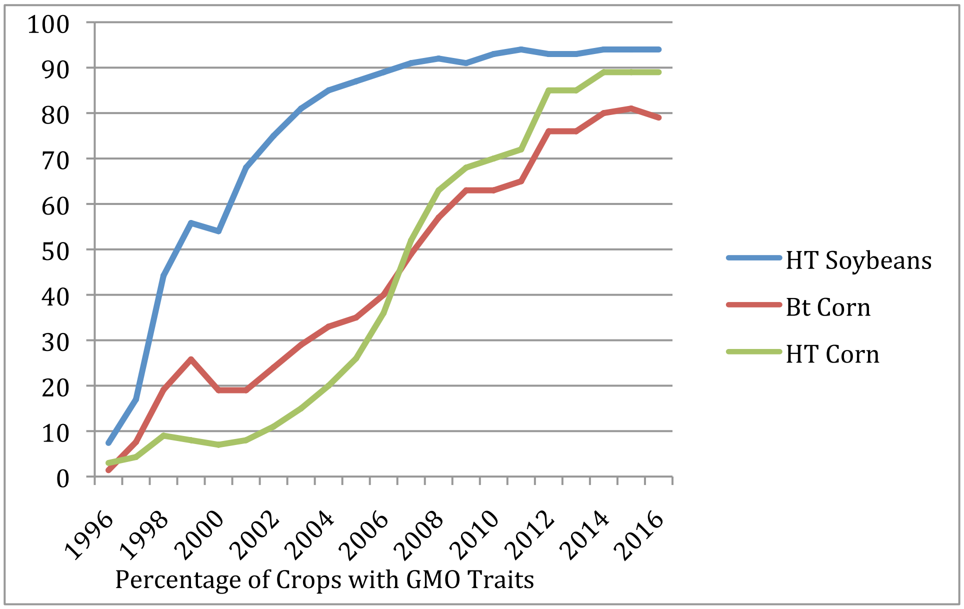

Figure 3. Adoption of GMO Crops, 1996 – 2016 (USDA 2016)

Current investments in research and development on GMOs prioritize applications in high-income countries (Conway 2012; Rosset, Collins, and Lappe 2000). International food policy expert Gordon Conway explains that, "private funding for agricultural research has grown but has tended to focus on the crops of developed countries where the [financial] returns have been greatest. This may be the reason why yield growth in maize and soybeans has been strong in recent years" (Conway 2012: 18). Furthermore, a large percentage of genetically modified crops do not in fact contribute to increasing food supplies. In 2016, only 8.6% of the corn grown in the United States went toward food for human consumption while 38.4% was used for animal feed and 28.9% was used as fuel ethanol (National Corn Growers Association 2017). The surge in genetically modified crop adoption has certainly enabled increased crop yields, yet in many cases they have not improved global food availability.

As the use of genetically modified crops has increased, scientists have found a variety of potential new applications for genetically modified crops. Genetically modified crops grow more quickly than conventional crops, and they can be modified in order to be resistant to droughts

(Bawa and Anilakumar 2012). Thus, the use of GMOs can greatly increase yields and can provide crop security in regions with frequent droughts. Genetic modification also allows scientists to improve the nutritional benefits of certain crops (Basu et al. 2010). For instance, genetically modified golden rice contains beta-carotene, a precursor to vitamin A, in order to combat vitamin A deficiency (Basu et al. 2010). Genetically modified crops can also be used to create edible vaccines, which protect populations with limited access to conventional vaccines from life-threatening diseases such as hepatitis B and tuberculosis (Basu et al. 2010).

Genetically modified crops are often presented as a valuable tool for low-income countries, and some believe genetic engineering will allow for a "second green revolution;" however, others argue that genetically modified crops should not necessarily be considered a miracle solution that will end world hunger (Glover 2010; Rivera-Ferre 2012; Scanlan 2013). As Peter Rosset, an agricultural ecologist and executive director of Food First, a nonprofit think tank focused on addressing global hunger, puts it, "we must be skeptical when Monsanto, DuPont, Novartis, and other chemical-biotechnology companies tell us that genetic engineering will boost crop yield and feed the hungry" (Rosset 2000: 8). Some policy experts note that in looking to genetically modified crops as a means of promoting food security we overlook the complexity of the causes behind hunger such as global inequality, wars, political turmoil, and climate change (Glover 2010; Rivera-Ferre 2012; Scanlan 2013). Several studies suggest that there is already enough food in the world to feed between ten and twelve billion people and that food distribution, rather than total yields, is the actual cause of undernutrition (Foley 2011; Latham 2000; Rivera-Ferre 2012). Increased food production in low-income countries may not universally improve nutritional outcomes because the poorest citizens may remain unable to afford food even in the event of surpluses (Glover 2010; Rivera-Ferre 2012; Scanlan 2013).

While agribusinesses provide genetically modified seeds to low-income countries, these seeds are not tailored to the needs of subsistence farmers in low-income countries who often utilize traditional, low-input, and non-mechanized agricultural techniques (Glover 2010; Rivera-Ferre 2012; Scanlan 2013). This may create dependency on the companies that supply seeds and strip smallholder farmers of their sovereignty over their own seeds. Furthermore, seeds provided by industry are unlikely to perform as well in impoverished nations as they do in wealthy nations where expensive inputs are required (Glover 2010; Rivera-Ferre 2012; Scanlan 2013).

In evaluating the risks and benefits of GMOs, some scientists also consider the possibility for negative health and environmental consequences (Bawa and Anilakumar 2013; Dona and Arvanitouannis 2009). By genetically engineering food crops scientists are changing plant genetics at a rate and on a scale that would never occur naturally (Aslaksen and Myhr 2006). As Dr. E. Ann Clark, a professor of plant agriculture at the University of Guelph puts it, the transition to genetically modified crops is “a global experiment with one condition and no control” (Peekhaus 2010: 419).

Numerous studies indicate that GMO consumption does not pose adverse health impacts for lab animals (Domingo 2007; Singh et al. 2006). Nevertheless, the fact that rodents that consume genetically modified crops for 90 days do not experience negative health consequences does not provide conclusive information regarding lifetime human consumption (Dona and Arvanitoyannis 2009; Holst-Jensen 2009; Querci et al. 2010). Some scientists note that the “absence of evidence of harm is not evidence of absence of harm,” and believe that much more information is needed to determine the possible risks posed by genetic modification (Chalmers 2001; Hilbeck et al. 2015).

Due to such scientific uncertainty, some scholars fear that over time genetically modified crops may begin to present detrimental human health impacts (Aslaksen and Myhr 2006; Bawa and Anilakumar 2012; Clark 2006; Finamore et al. 2008; Hilbeck et al. 2015; Kroghsbo et al. 2008). To date, there are no epidemiological studies regarding GMO consumption and health outcomes (Hilbeck et al. 2015). Certain studies provide limited evidence that consuming genetically modified crops may lead to immune dysregulation, causing immune responses that are either inappropriately weak or inappropriately robust in rats and mice (Finamore et al. 2008; Kroghsbo et al. 2008). Furthermore, some scientists are concerned that non-allergenic proteins could become allergenic when they are transferred to a different plant and that genetically modified crops may potentially increase allergic reactions (Domingo and Bordonaba 2011; Dona and Arvanitouannis 2009). Others believe that genetically modified food crops may be a cause of antibiotic resistance or that they may contain more toxins that conventional crops (Bawa and Anilakumar 2012).

There is also concern regarding the potential environmental impacts of genetically modified crops. It is impossible to predict exactly how a GMO crop will interact with its environment (Clark 2006). Genetically modified crops may mix with native varieties and thereby decrease the biodiversity of certain plant species (Peekhaus 2010). Some scientists are concerned GMOs may compromise other crops and that they could have negative consequences for non-target organisms (Clark 2006). Others note that rapid adoption of herbicide resistant crops has allowed for the development of herbicide resistant "super weeds," ultimately posing new problems for farmers and requiring even greater pesticide application (Aslaksen and Myhr 2006). It may be difficult to determine the environmental impacts of genetically modified crops because there may be a lag time of decades or even centuries before a non-native species becomes an invasive species (Clark 2006).

In addition to considering the potential health and environmental impacts of genetically modified crops, it is necessary to assess the risks associated with the use of herbicides on genetically modified crops. Herbicide resistance is one of the traits that is commonly introduced into seeds allowing farmers to spray entire fields with herbicides in order to easily kill weeds without killing crops. Genetically modified corn and soybeans can tolerate glyphosate (marketed in a mixture called Roundup), the most commonly used herbicide in the world (Bai and Ogbourne 2016). "Roundup Ready" crops now comprise more than 90% of soybeans and corns in the United States (Landrigan 2015). In 2014, 113 million kilograms of glyphosate were applied to crops in the United States (Landrigan 2015). As glyphosate usage increases, "Roundup Ready" crops become more resistant to the herbicide, and glyphosate usage may continue to increase (Green 2016). The World Health Organization's International Agency for Research on Cancer (IARC) classifies glyphosate as "probably carcinogenic to humans" (IARC 2015). The majority of glyphosate is mineralized after it is applied to crops; however, under certain conditions glyphosate residue may persist in water, soil, and plants (Annett, Habibi, and Hontela 2014). These risks add another layer of complexity to disputes regarding the safety of GMOs.

Conclusive safety testing has failed to match the pace of the implementation of new genetically modified crops (Aslaksen and Myhr 2006; Krimsky 2012). Evaluating the safety of GMOs may be based on the concept of "substantial equivalence" (Bawa and Anilakumar 2013). This means that if the nutritional content of a new genetically modified crop appears to be almost identical to an existing conventional crop scientists may assume that the genetically modified crop will behave the same may the conventional crop does (Bawa and Anilakumar 2013). However, some scientists believe that even if a GMO crop is substantially equivalent to a conventional crop, genetic modification may have unintended consequences, and thus rigorous safety testing should be required for each new crop that is introduced (Dona and Arvanitouannis 2009; Domingo and Bordonaba 2011).

Governments typically draw on cost benefit analyses in order to decide whether or not the benefits of genetically modified crops outweigh the risks. In the case of genetically modifying crops or other issues evolving potential environmental risks, conducting cost benefit analyses is far from straightforward (Aslaksen and Myhr 2006). Some scientists feel that cost benefit analyses should not determine policies regarding GMOs (Domingo and Bordonaba 2011; Zhang and Shi 2011). Instead, they believe we should follow the precautionary principle, which states that if a certain activity raises threats to the environment or human health, policy makers should take precautionary measures even in the absence of any conclusive evidence of negative health or environmental consequences (Aslaksen and Myhr 2006; Hillbeck et. al 2015).

Others feel that the risks of genetically modified crops are negligible and that stricter GMO regulations are obstacles to both technological advancement and food security in low-income nations (Miller and Conko 2004; Paarlberg 2009). Certain scholars believe that delayed deployment of genetically modified golden rice due to its lack of profitability caused people to die of vitamin-A deficiency unnecessarily (Bouis 2007; Potrykus 2012). Food policy expert Robert Paarlberg (2009, 2010) argues that the European Union's implementation of cautious GMO regulations has prevented African governments from adopting genetically modified crops. He feels that this is a lost opportunity, and believes wealthy nations' precautionary measures may have a human cost in multiple sub-Saharan African countries where addressing widespread undernutrition remains crucial (Paarlberg 2009).

GMO proponents have compared those concerned about the safety of genetically modified crops to climate change deniers and suggest that they are “anti-science” (Krimsky 2015). This may be an inappropriate comparison. There is scientific consensus regarding human involvement in climate change, and this level of consensus is not yet present in the case of genetically modified crops (Bawa and Anilakumar 2013; Domingo and Bordonaba 2011; Dona and Arvanitouannis 2009; Magana-Gomez and Calderon de la Barca 2008; Vendomois et al. 2010; Zhang and Shi 2011). Controversies around GMOs largely reflect management of the risks and benefits of a new agricultural technology in the presence of scientific uncertainty. Opposition to genetic modification stems from a desire to be cautious in the use of a new technology that may have irreversible consequences. Despite claims that those who question the safety of genetically modified crops are “anti-science,” multiple scholars have noted that further safety testing of GMOs is necessary (Domingo and Bordonaba 2011; Dona and Arvanitouannis 2009; Zhang and Shi 2011). Recent reviews of the scientific literature highlight the fact that the number of research groups suggesting that genetically modified crops are as safe as conventional crops is roughly equal to those raising concerns about potential adverse effects (Bawa and Anilakumar 2013; Domingo and Bordonaba 2011).

Scholars also note that the companies responsible for commercializing genetically modified seeds conduct a significant portion of genetically modified crop safety testing (Bressler 2008; Lotter 2008; Peekhaus 2010). This raises the question of whether the integrity of the available body of scientific studies on genetically modified crops has been compromised due to corporate involvement. It is not the intention of this thesis to offer an opinion as to whether or not GMOs are safe or whether they have a place in the global food supply. Rather, what follows is an exploration of how the very corporations that produce GMO seeds have influenced the scientific dialogue on genetically modified crops.

Chapter 2: Industry Research Priorities and Conflicts of Interest in GMO Research

Multiple scholars have expressed concern that corporate sponsorship functions to set the priorities for agricultural biotechnology research at universities and that these priorities may be at odds with the public interest (Bressler 2008; Keeney 2014; Krimsky 2015; Lotter 2008; Myhr and Traavik 2003; Peekhaus 2010; Scott 2003; Schwab 2012). Wilhelm Peekhaus, a scholar of information science at the University of Wisconsin Milwaukee, contends that partnerships between agricultural biotechnology corporations and universities are leading to the rise of what he describes as "neoliberal universities," explaining that, "the effects of neoliberalism can be seen in the generation of conflicts of interest within the university, the skewing of research, expanding industry–academia linkages, and the indoctrination of a new generation of academic researchers motivated predominantly by private rather than public interest" (Peekhaus 2010: 415). Michael Bressler, a political science professor at Long Beach City College, believes that corporate involvement in agricultural biotechnology research has created "a system of privatized knowledge production which influences scientific research by impinging on research design, interpretation, transparency and publicity" (Bressler 2008: 1). Similarly, Don Lotter, an agro-ecologist at the University of California Davis, describes how the shift from public to private funding for university research has led to "academic capitalism," and that opportunities for private gain dictate too many universities' priorities (Lotter 2008).

Dr. Elson Shields, an entomologist at Cornell University, expresses frustration regarding the way agribusiness funding has constrained research endeavors: "People are afraid of being blacklisted. If your sole job is to work on corn insects and you need the latest corn varieties and the companies decide not to give it to you, you can't do your job" (Peekhaus 2010: 419). When asked to offer his opinion, David Schubert, a cell biologist at the Salk Institute expressed similar sentiments noting that, "People who look into safety issues and pollination and contamination issues [of genetically modified crops] get seriously harassed" (Waltz 2009: 28). Other scientists also agreed, and in 2009 twenty-six crop researchers wrote to the United States Environmental Protection Agency expressing their concerns:

> Technology/stewardship agreements required for the purchase of genetically modified seed explicitly prohibit research. These agreements inhibit public scientists from pursuing their mandated role on behalf of the public good unless the research is approved by industry. As a result of restricted access, no truly independent research can be legally conducted on many critical questions regarding the technology, its performance, its management implications, IRM [insect resistance management], and its interactions with insect biology. Consequently, data flowing to an EPA Scientific Advisory Panel from the public sector is unduly limited. (U.S. EPA 2009)

This letter was anonymous, and the writers explained that, "The names of the scientists have been withheld from the public docket because virtually all of us require cooperation from industry at some level to conduct our research" (U.S. EPA 2009). The fact that the writers wished to remain anonymous illustrates the difficulty of the predicament of scientists who rely on industry but also wish to conduct research that is not in line with business interests. Thus, the potential for creating turmoil or negatively impacting their chances of receiving grants in the future may prevent scientists from looking into topics that otherwise seem salient.

While much of the literature regarding industry's influence on GMO research focuses on academics allied with agricultural biotechnology companies, the organic food industry has also collaborated with researchers (Lipton 2015). For instance, Charles Benbrook, an expert on agricultural economics, came to Washington State University after working for the Organic Center, which is funded by organic food companies (Lipton 2015). While at Washington State University, Benbrook received grants from Organic Valley, Whole Foods, Stonyfield Farm, and United Natural Foods Inc. Stonyfield Farm provided funding for Benbrock to travel to Washington, D.C. and support lobbying efforts requiring GMO labeling (Lipton 2015). Although the organics industry has created conflicts of interest just as the agricultural biotechnology industry has, the financial resources available to the organics industry simply do not compare to those of the world's largest seed, pesticide, and herbicide manufacturers. Thus, the organic industry's financial influence in the scientific debate is comparably insignificant to that of the agricultural biotechnology industry.

Scholars' concerns regarding industry's role in scientific research seem to be warranted. A recent article in the *New York Times* suggests that Monsanto hired academics to put their names on studies written by the company (Hakim 2017). Internal emails indicate that Monsanto published papers on the safety of glyphosate, the herbicide they produce, and attributed the studies to academic scientists (Hakim 2017). Several recent studies also suggest that conflicts of interest (COIs) may impact the integrity of peer-reviewed studies on genetically modified crops (Diels et al., 2011; Guillemaud, Lombaert & Bourguet, 2016; Krimsky, & Schwab, 2017; Myhr & Traavik, 2003; Robinson et. al, 2013; Sanchez, 2015; Schwab, 2012). In 2016, the nonpartisan National Academies of Sciences, Engineering, and Medicine (NASEM) published a report on genetically modified crops (National Academies of Sciences, Engineering, and Medicine 2016). A recent study reported that six out of the twenty members who wrote this report were subject to financial conflicts of interest as they received industry funding for other research while working on the NASEM report (Krimsky & Schwab 2017). Certain scholars also point out that government agencies responsible for food safety evaluations are influenced by conflicts of interest (Robinson et al. 2013). A 2013 report notes that the European Parliament refused to approve the European Food Safety Authority's (EFSA) budget due to conflicts of interest (Robinson et al. 2013). The European Court of Auditors concluded that the EFSA's policies for managing conflicts of interest were inadequate (Robinson et al. 2013).

Two recent analyses of the literature focus on conflicts of interest in the available body of published studies exploring the possible health effects of genetically modified food and genetically modified animal feed. A 2011 study reviewed 94 reports on genetically modified crop food and feed safety testing and found that 44 articles, or 47%, contained a financial COI, a professional COI or both (Diels et al. 2011) (Table 1). In 13 studies or 14% of the sample, the authors could not determine whether a COI was in fact absent or went undetected due to lack of information available on financial sponsorship or author affiliation (Diels et al. 2011). This study also found that articles in which conflicts of interest were present were correlated with outcomes suggesting that genetically modified crops were as safe and nutritious as their conventional counterparts (Diels et al. 2011).

In 2015, a similar study with a larger sample size reviewed 698 reports on genetically modified crop food and feed safety testing. This study found that 25.8% of articles had COIs while 15.9% of the articles sampled did not declare their funding source making it impossible to determine whether or not the authors had conflicting interests (Sanchez 2015). In certain areas of GMO research, up to 66.7% of articles were subject to conflicts of interest (Sanchez 2015) (Table 2). Despite these alarming findings, the author, Miguel Sanchez, concludes that "claims that there is not sufficient peer-reviewed literature evaluating GM food/feed safety issues or that

COIs prevail in the published literature are not supported by this analysis" (Sanchez 2015: 137). This conclusion seems to be unsupported by Sanchez's data showing that conflicts of interest were present in at least a quarter and perhaps as many as 40% of the articles he sampled (Sanchez 2015). Sanchez declares conflicting financial interests, and the contact information he provides indicates that he is the executive director of ChileBio (Sanchez 2015). ChileBio is a Santiago, Chile based agricultural biotechnology corporation, which produces genetically modified seeds (Chilebio 2017).

A third study explores conflicts of interest in peer-reviewed articles on the efficacy and durability of genetically modified crops (Guillemaud et al. 2016). Of the 672 studies examined, the authors found conflicts of interest in approximately 40%, and 22% of the studies failed to provide declarations of funding sources (Guillemaud et al. 2016, Table 2). About 7% of all articles sampled declared a conflict of interest although roughly 21% of the total articles listed one or more authors who were employed by agricultural biotechnology companies, suggesting that authors may not declare existing conflicts of interest (Guillemaud et al. 2016). The authors also note that "compared to the absence of COI, the presence of a COI was associated with a 50% higher frequency of outcomes favorable to the interest of the GM crop company" (Guillemaud et al. 2016). Although this study focuses on articles addressing the efficacy and durability of genetically modified crops rather than safety concerns, it is suggestive of a larger trend in which substantial portions of studies are subject to conflicts of interest.

Table 1. Summary of Findings in Reviews on Conflicts of Interest in GMO Research

Study	Number of Articles Reviewed	Percentage that did not Declare Funding	Percentage with COIs
Diels et al. (2011)	94	14%	47%
Sanchez (2015)	698	15.9%	25.8%
Guillemaud et al. (2016)	672	22%	40%

Table 2. Conflicts of Interest and Declaration of Funding Sources in Studies on GMO Safety[1]

Research area	Number of studies	Percentage that did not declare funding	Percentage with COIs
Allergenicity potential	46	8.7%	19.6%
Animal health	204	16.7%	16.2%
Animal nutrition	111	18.9%	53.2%
Equivalence	106	13.2%	43.4%
Mycotoxins	18	22.2%	66.7%
Processing	18	11.1%	11.1%
Traceability and/or digestion	91	19.8%	11.0%
Unintended effects	104	13.5%	8.7%
Total	698	15.9%	25.8%

[1] Adopted from: Sanchez, Miguel A. "Conflict of interests and evidence base for GM crops food/feed safety research." *Nature biotechnology* 33, no. 2 (2015): 135-137.

The data presented in these studies raises the issue of how conflicts of interest may impact the integrity of scientific inquiry into the safety of genetically modified crops. The number of articles in which researchers were unable to determine whether scientists were subject to conflicts of interest reflects a lack of transparency. Both the existence of conflicts of interest and the difficulty in determining whether authors were subjected to conflicts of interest has the potential to erode trust in peer-reviewed articles among scientists as well as public audiences. To date only two studies have addressed the prevalence of conflicts of interest in GMO safety research, and one study has addressed the prevalence of conflicts of interest in GMO efficacy and safety research (Diels et al 2011; Sanchez 2015). None of the available studies provides an analysis of which journals publish a large percentage of articles containing conflicts of interest. Additional research may prove to be useful for those attempting to implement measures to manage conflicting interests among research groups as well as among the editorial boards of journals.

Chapter 3: Conflicts of Interest in Scientific Studies on GMO Safety

I analyzed a sample of scientific studies on genetically modified crop safety to examine the prevalence of conflicts of interest, the accuracy of disclosure statements, and the share of conflicts of interest in certain academic journals. In order to gather a random sample of articles on GMO safety, I conducted a search of the Scopus database using the keywords "GMO" OR "transgenic" OR "genetically modified" OR "genetically engineered" AND "feed" OR "feeding" OR "safety." The search was limited to articles in English published in 2008 or later. Of the 4,652 hits, 119 studies involved either comparing the composition of GMOs to conventional crops or feeding genetically modified as well conventional crops to lab animals. I used these articles as the sample for analysis.

The 119 articles in the sample came from different 47 scientific journals with authors from 28 countries. With four exceptions, no more than three studies came from the same journal. There were 5 articles from *Transgenic Research*, 12 articles from *PLoS ONE*, 15 articles from *Regulatory Toxicology and Pharmacology*, and 26 articles from *Food and Chemical Toxicology* (Table 3).

Table 3. Journals in Sample

Journal Name	Number of Articles from Journal
Food and Chemical Toxicology	26
PLoS ONE	12
Regulatory Toxicology and Pharmacology	15
Transgenic Research	5
Other Journals (each with fewer than five articles)	61

Using author affiliations and funding information, I determined whether studies were subject to conflicts of interest. For the purpose of this research, I classify a study as containing a conflict of interest if one or more of the authors are employees of or consultants for an agricultural biotechnology corporation or if the study was completely or partially funded by an agricultural biotechnology company. I found that 34 of the articles or 28.6% of the sample were subject to conflicts of interest (Figure 4). In the case of 31 articles, it was possible to determine if the study was subject to a conflict of interest from the author affiliations listed at the top of the studies. Author affiliations included the world's six largest agricultural biotechnology corporations: BASF, Bayer, Dow, DuPont, Monsanto, and Syngenta, as well as Pioneer Hi-Breed, which is a branch of Dupont and Nofima AS, a Norwegian agricultural biotechnology corporation (Howard 2009). In two articles, authors declared conflicting interests because they worked as consultants for the agricultural biotechnology industry. One article's authors were all affiliated with universities, but they disclosed that their research had been funded exclusively by industry. In the case of ten articles (8.4% of the sample) the authors did not provide enough information to determine whether a conflict of interest was present.

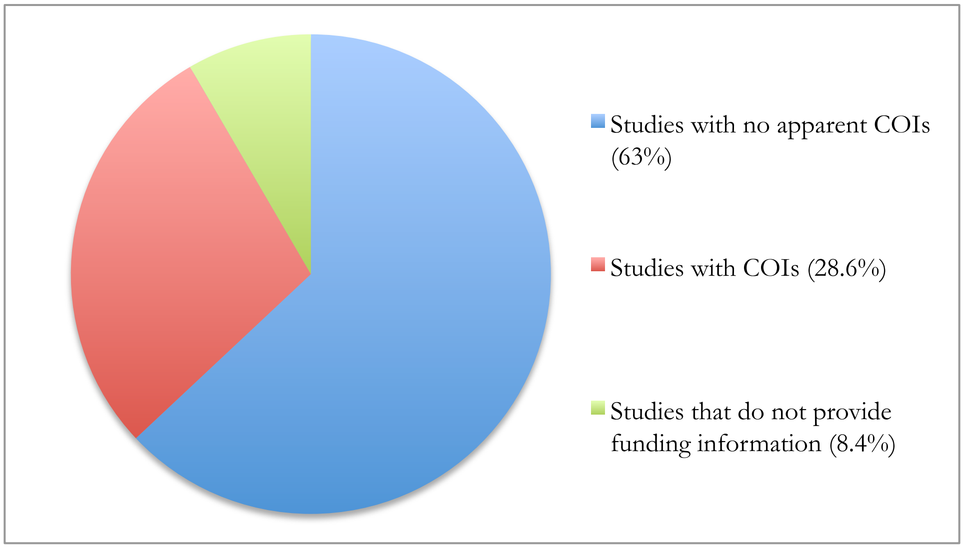

Figure 4. Prevalence of Conflicts of Interest in Sampled Articles

Of the 34 articles that were subject to conflicts of interest, fourteen articles included statements acknowledging that the authors may have had conflicting interests (Figure 5). Five of the articles listing industry affiliated authors did not declare their funding sources or acknowledge conflicts of interest. Fifteen of the articles that were subject to conflicts of interest declared that the authors did not in fact have conflicting interests. In 11 cases, the authors acknowledged that their research had been funded by agricultural biotechnology companies and then went on to declare that they had no conflicts of interest (Figure 6).

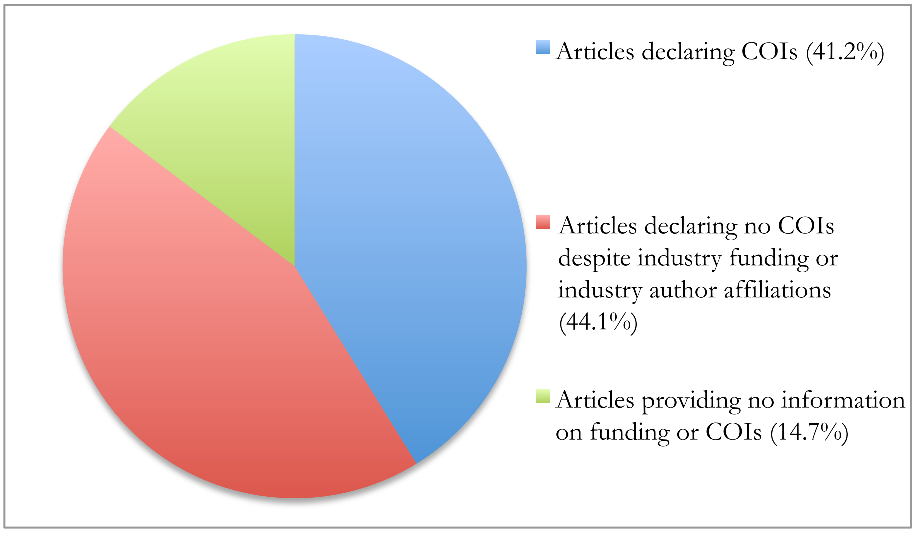

Figure 5. Acknowledgement of Existing COIs

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Figure 6. Example of a Conflict of Interest Statement (Appenzeller et al. 2009) highlighting added.

In addition to being the journals contributing the most articles, *Regulatory Toxicology and Pharmacology* and *Food and Chemical Toxicology* were also the source of the largest numbers of conflicts of interest. These two journals accounted for 24 conflicts of interest or

70.6% of the total apparent conflicts of interest in the sample. In the case of *Regulatory Toxicology and Pharmacology* 11 out of 15 articles (73.3%) were subject to conflicts of interest, and in the case of *Food and Chemical Toxicology* 13 out of 26 articles (50%) were subject to conflicts of interest (Table 4).

Table 4. Prevalence of COIs in Most Common Journals in Sample

Journal Name	Number of Articles from Journal	Percentage of total Sampled Articles from Journal	Percentage of Articles from Journal Subject to COIs
Food and Chemical Toxicology	26	21.8%	50%
PLoS ONE	12	10.1%	8.3%
Regulatory Toxicology and Pharmacology	15	12.6%	73.3%
Transgenic Research	5	4.2%	0%

The data from this sample support previous research as one study found that 47% of studies on GMO safety were subject to conflicts of interest and one found that 25.8% were (Diels et al 2011; Sanchez 2015). One should note that my finding that 28.6% of the sampled studies are subject to conflicts of interest signifies that *at least* 28.6% of the 119 articles contained conflicts of interest. In the case of ten articles, or 8.4% of the sample, the authors did not indicate who had sponsored their research, and some of these articles may have received industry funding. It is also possible that studies I deemed as not disposed to vested interests are in fact subject to conflicts of interest as authors at universities may not declare that they work as industry consultants (Krimsky 2015; Swchab 2012).

These findings indicate that scientists often fail to disclose existing conflicts of interest properly. Only 41.2% of the studies that were subject to conflicts of interest included statements informing readers that the authors had conflicting interests. Fifteen studies (44.1% of the sample) stated that they did not have conflicts of interest despite listing industry author affiliations or acknowledging that industry provided funding for their research. This suggests that conflict of interest statements may be inaccurate and that journals may attempt to conceal vested interests. While it is possible that there is some level of misunderstanding regarding what constitutes a conflict of interest, it is more likely that the authors are employing a deceptive strategy in the hope that readers will overlook potential biases. In the case of these articles, one can fairly easily discern that conflicts of interest are present by taking note of the author affiliations or the funding sources. However, a problem exists if readers are skimming through articles and assume that conflict of interest statements are accurate.

It is likely no coincidence that the two most common journals in the sample, *Food and Chemical Toxicology* and *Regulatory Toxicology and Pharmacology,* each have a very high prevalence of articles that are subject to conflicts of interest (50% and 73.3% respectively). Bryan Delaney, one of the four co-editors of *Food and Chemical Toxicology*, is an employee of DuPont (Food and Chemical Toxicology 2017). According to *Independent Science News* multiple members serving on *Food and Chemical Toxicology*'s editorial board also have ties to industry (Latham, Robinson, and Smith 2013). Scholars have also expressed concern about conflicts of interest at *Regulatory Toxicology and Pharmacology* (Guterman 2002). In 2002, scientists at the Center for Science in the Public Interest organized a letter to *Regulatory Toxicology and Pharmacology* (Center for Science in the Public Interest 2002). Forty-five scientists signed the document expressing concerns about the objectivity of the journal:

> We write to you to express our concerns about apparent conflicts of interest, lack of transparency, and the absence of editorial independence of the journal Regulatory Toxicology and Pharmacology (RTP), which you publish [...] RTP serves as a convenient venue for the publication of industry research and gives the credibility of a peer-reviewed journal to articles that may not have been subjected to full and meaningful independent

> review [...] RTP routinely fails to disclose relevant conflicts of interest. (Center for Science in the Public Interest 2002)

The letter also indicated that sixteen members of *Regulatory Toxicology and Pharmacology*'s editorial board, including the editor in chief, were subject to conflicts of interest (Center for Science in the Public Interest 2002). The fact that vested interests impact entire scientific journals suggests that the prevalence of conflicts of interest may be even higher than the previously discussed data indicate.

Determining the exact number of conflicts of interest present in articles on the safety of genetically modified crops is quite difficult. In many cases, industry scientists may not acknowledge the presence of conflicts of interest. Industry employees control the editorial boards of certain journals. This may prevent studies suggesting potential adverse impacts of genetically modified crops and associated pesticides and herbicides from being published in certain journals. While this sample does not encompass the entirety of articles on GMO safety published in the last decade, it suggests that a significant portion of studies is subject to conflicts of interest.

Industry funding extends beyond sponsorship of scientific journals, and university researchers may also be subject to conflicts of interest. The following section is an analysis of funding sources for agricultural biotechnology research. Despite the limited availability of data, examining the funding sources that make university agriculture research possible provides further insight into the potential for bias in GMO evaluations.

Chapter 4: University Funding Sources and Industry Academia Relationships

Although there have been numerous recent publications addressing the challenges raised by conflicts of interest in agricultural biotechnology research, my review of the literature suggests that numerical data regarding funding sources for agricultural biotechnology research remains somewhat limited. However, one source, a 2012 report published by Food and Water Watch, a Washington, D.C. nonprofit, includes a detailed analysis of the percentage of funding universities received from corporations (Food and Water Watch 2012). According to this report, a substantial number of agricultural biotechnology departments at land-grant universities receive 40 to 50% of their funding from private sponsors (Table 5) (Food and Water Watch 2012).

Table 5. Academic Departments Receiving Corporate and Trade Association Funding[2]

University Department	Years	Private Grants	Percent of Department Grants	Sponsors Include
Texas A&M Soil and Crop Sciences	2006–10	$13.0 million	56 %	Monsanto, Cotton Inc., Pioneer Hi-Bred
Iowa State University Agronomy	2006–10	$19.5 million	48%	Dow, Monsanto, Iowa Soybean Association
Texas A&M University Institute of Plant	2006–10	$1.8 million	46%	Cotton Inc., Chevron Technology
University of Illinois Crop Sciences	2006–10	$18.7 million	44%	Monsanto, Syngenta,
University of Missouri Plant Sciences	2007–10	$16.4 million	42%	Phillip Morris, Monsanto, Dow Agroscience,
Iowa State University Plant Pathology	2006–10	$10.7 million	38%	United Soybean Board, Dow
Purdue Agronomy	2010–11	$2.5 million	31%	Dow, Deere & Company
University of California Plant Sciences	2006–10	$33.6 million	28%	Chevron Technology

[2]Adopted from Food and Water Watch. "Public Research, Private Gain." Apr. 2012. Web. 30 Dec. 2016.

Tim Schwab, the author of the Food and Water Watch report, noted that many universities were not transparent regarding their research funding. (T. Schwab, personal communication, January 3, 2017). Food and Water Watch's report obtained much of the data only after submitting a Freedom of Information Act request, and the process took many months. Schwab emphasized the need for more research like his own, and suggested that an attempt to conduct a more current examination of funding sources for agricultural biotechnology research would likely prove to be a worthwhile endeavor. Despite the limited availability of data, examining the funding sources that make university research possible highlights the potential for conflicts of interest in research on genetically modified crops. This section provides an analysis of funding sources for agricultural biotechnology research.

According to a 2017 article in *U.S. News & World Report*, the top 12 universities for Agricultural Sciences include the University of California Davis, Cornell University, the University of Massachusetts Amherst, the University of Florida, Harvard University, The University of Minnesota Twin Cities, the University of Wisconsin Madison, Rutgers University, the University of Illinois Urbana-Champaign, Michigan State University, Iowa State University, and Ohio State University. I removed the University of Massachusetts Amherst and Harvard University from my sample as neither university has departments that specialize in agricultural biotechnology. The remaining ten universities are included in the following analysis. While I recognize that the U.S. News & World Report is only one measure of the quality of academic programs, it provided a straightforward method for selecting a sample of universities to contact.

After speaking to representatives in the offices of sponsored research at each of the ten universities, I found that only five provided some form of publicly available information regarding research funding. I was unable to obtain any data on research funding from UC Davis, The University of Minnesota, Rutgers University, Michigan State, or Ohio State. Although it is possible that there were data sets available in locations other than university websites, the staff members in the office of sponsored research for these five universities were not aware of any such publicly available data sets. Cornell, the University of Illinois, the University of Florida, and Iowa State published reports with information about research funding. However, Iowa State was the only institution with a publicly accessible record of each of the grants received by each academic department rather than a more general report of grant funding for the entire university.

Cornell University

Cornell University's most recent report indicates that 4.2% of funding was provided by industry but does not provide information regarding research funding for different departments. However, Cornell is home to the Alliance for Science. The Alliance states that their mission is to "promote access to scientific innovation as a means of enhancing food security, improving environmental sustainability and raising the quality of life globally" (Alliance for Science 2017). The Alliance for Science adamantly supports the use of GMOs, and its public website includes information regarding the use of genetically modified crops as a means of improving food security in low-income countries (Alliance for Science 2017). One of its recent publications is entitled "the GMO safety debate is over" (Alliance for Science 2017). Certain scientists opposed to Cornell's mission have called the Alliance for Science "Cornell's propaganda arm" (*Independent Science News* 2016). The Alliance for Science receives funding from the Bill and Melinda Gates Foundation, and the foundation holds around 23 million dollars in Monsanto shares (Vidal 2010). In August 2010 the *Wall Street Journal* published information regarding the foundation's portfolio investments. Subsequently, the Bill and Melinda Gates Foundation received hundred of postcards from activists asking that the foundation divest from Monsanto and other agribusinesses (Heim and O'Hagan 2010). Although it is funded by a charitable organization, the Alliance for Science works closely with Monsanto, and the Alliance for Science has been very critical of scientists suggesting that further safety testing of genetically modified crops is necessary (Alliance for Science 2017).

The University of Florida

According to the University of Florida's 2016 annual report, the university received $724.3 million in total grant money and corporations and trade associations provided $67.3 million, or 9.3% of total funding. Of the $724.3 million of total grant money, $140.1 million or 19.3% of the total, went to the Institute of Food and Agricultural Studies. However, the report does not provide information regarding how much of the sponsorship for the Institute of Food and Agricultural Studies was from industry.

There is also some evidence that corporate influence at the University of Florida may extend beyond the research grants documented in publicly available annual reports (Lipton 2015). According to the *New York Times*, Kevin Folta, the chairman of the University's Horticultural Science Department, has been involved in so called "biotechnology outreach" (Lipton 2015). Folta received an undisclosed amount in special grants from Monsanto for his public defense of genetically modified crops (Lipton 2015). In 2013, the Counsel of Biotechnology Information, which is run by BASF, Bayer, Dow Chemical, Dupont, and Monsanto, requested Folta's assistance with their website called "GMO answers" (Lipton 2015). According to an executive from Ketchum, the public relations company involved with creating content for the website, "GMO answers" was intended to "build trust, dialogue and support for biotech in agriculture" and "help explain in an independent voice what GMOs are" (Lipton 2015). Since Ketchum provided Folta with drafts of the content to be published on the website this website did not truly offer the “independent voice” it claimed to provide (Lipton 2015). Following his participation with “GMO answers,” Folta received a $25,000 grant from Monsanto allowing him to travel and give presentations about the genetically modified crop industry (Lipton 2015).

The University of Illinois Urbana-Champaign

The University of Illinois’s most recent factbook does not provide information regarding grants received by specific departments. Nevertheless, according to the *New York Times*, Bruce Chassy, the University of Illinois’s former head of the Department of Food Science and Human Nutrition, received sponsorship for his collaboration with Monsanto (Lipton 2015). A series of emails between Chassy and Monsanto employees was released following a Freedom of Information Act request filed by U.S. Right to Know, a non-profit organization funded by the Organic Consumer’s Association (Lipton 2015). An October 19, 2011 email from Chassy to Sheryl Evertowski, an administrative assistant at Monsanto, read, “A letter should be enclosed that says the enclosed check is an unrestricted gift payable to the University of Illinois Foundation in support of the biotechnology outreach and education activities of professor Bruce M. Chassy” (*New York Times* News Documents 2015). Chassy’s emails also indicate that he was involved in Monsanto’s efforts to dissuade the E.P.A. from following through with its proposal to impose more stringent regulations on pesticides used on genetically modified seeds (Lipton 2015). Along with other scientists and industry representatives, Chassy met with Steven Bradbury, the director of the E.P.A.’s Office of Pesticide Programs at the time, prior to the agency’s decision not to implement more restrictive pesticide regulations (Lipton 2015).

The University of Wisconsin Madison

According to the University of Wisconsin Madison's most recent data digest, the university received $901.5 million of funding for research in fiscal year 2014-2015. Business and industry funding accounted for $36.2 million or 4% of total funding. The College of Agriculture and Life Sciences received $64.4 million or 7.1% of total external sponsorship. Non-federal funding comprised $17 million of funding for the College of Agriculture and Life Sciences or 26.4% of the college's total research grants. The data digest does not provide information regarding what portion of non-federal funding is from industry and what portion is from foundations, local and state government, and nonprofit organizations. These numbers indicate that between zero and 26.4% of the College of Agriculture and Life Sciences research funding was provided by industry. It remains impossible to determine the percentage of industry sponsorship for the College of Agriculture and Life Sciences without more information. The funding information for the four previously mentioned universities is summarized in Table 6.

Table 6. Percentage of University Funding from Industry

University	Percentage of Industry Funding	Year(s)
Cornell University	4.2%	2011-2012
The University of Florida	9.3%	2016
The University of Wisconsin Madison	4.0%	2014 - 2015
Iowa State University	9.9%	2015 - 2016

Iowa State University

Iowa State University provides a publicly available record of all of the grants received by professors. Using this information, I was able to calculate the total funding and the percentage of corporate and trade association research funding for four relevant departments. In fiscal year 2015, the departments of Agricultural and Biosystems Engineering, Agronomy, Entomology, and Plant Pathology received a total of $18,742,420 of funding, and $8,150,013 or 43.5% of the total grant money was supplied by 39 different private companies and trade associations. Each of the individual departments received between 25.8% and 84.9% of their total funding from corporations and trade groups (Table 7). In fiscal year 2015, grants from four corporations and trade associations comprised 31% of total grant money received by the four previously mentioned departments (Table 8). In fiscal year 2016, the four departments received a total of $21,074,328 of funding, and $10,104,947 or 47.9% of the total grant money was supplied by 33 corporations and trade associations. The percentage of corporate and trade association grants received by individual departments was between 22.4% and 65.8% of their total funding. Sponsorship from five different companies and trade associations made up 29.9% of total grant money received by the departments of Agricultural and Biosystems Engineering, Agronomy, Entomology, and Plant Pathology.

Table 7. Percentage of Corporate and Trade Association Grants by Department at Iowa State University in 2015 and 2016

Department	Percentage of Total Grant Funding from Corporations and Trade Associations (2015)	Percentage of Total Grant Funding from Corporations and Trade Associations (2016)
Agricultural and Biosystems Engineering	43.2%	65.8%
Agronomy	25.8%	22.4%
Entomology	84.9%	61.1%
Plant Pathology	43.3%	30.8%

Table 8. Funding for Agricultural and Biosystems Engineering, Agronomy, Entomology, and Plant Pathology Departments at Iowa State University From Select Corporations and Trade Associations in 2015 and 2016

Corporation or Trade Association	Year	Percentage of Funding Provided
Bayer Crop Science	2015	5.7%
Deere & Company	2015	9.9%
DuPont	2015	2.6%
Iowa Soybean Association	2015	12.8%
Bayer Crop Science	2016	2.5%
Deere & Company	2016	11.7%
DuPont	2016	2.9%
Iowa Soybean Association	2016	8.8%
Monsanto Company	2016	4%

A mixture of quantitative data and anecdotal information suggests that scientists at four out of the five universities for which I was able to find data work closely with industry. While industry grants provide scientists with valuable resources, corporate sponsorship also creates the potential for creating bias in university agricultural research. In the cases of Florida State University, Illinois State University, and Iowa State University it is apparent that scientists received large grants from industry for research, "biotechnology outreach," and lobbying of federal agencies. Information about Cornell's Alliance for Science and partnerships between department heads and Monsanto at Florida State University and Illinois State University raise concerns about conflicts of interest and the ability of scientists to conduct independent research and publish studies that may be unpopular with industry.

The relatively small quantity of quantitative data discussed above is representative of the scarcity of the available information regarding funding sources for university research. Nine out of the ten universities included in my sample are public universities; Cornell is one of three semi-private land grant universities in the United States. Half of the universities I contacted did not have publicly available information on grant sources, despite the fact that they are public institutions. The lack of available data makes it difficult for the public to assess the growing role of industry in university research. It is likely possible to obtain more data from these universities through the submission of a Freedom of Information Act request; however, the amount of time required makes this process fairly inaccessible.

Even if universities do provide funding information, the presentation of the data may not make it possible to examine grant sources for specific academic departments as was the case with Cornell University, the University of Florida, and the University of Wisconsin Madison. While industry funding comprises a relatively small percentage of the total grant money at these universities, it is still possible that certain departments receive large amounts of industry funding and that certain professors conducting research on genetically modified crops are subject to conflicts of interest. For instance, industry grants comprised fewer than 10% of Iowa State University's total sponsorship in financial years 2015 and 2016, but individual departments received well over half their funding from industry. Other universities may reflect the same trends. Even if the total percentage of corporate grants appears to be low, a single data point may fail to provide insight into funding for agriculture programs that may receive the majority of their funding from corporations and trade associations.

Although the data from Iowa State University alone does not allow us to draw conclusions regarding the influence of industry funding for university agricultural research throughout the entire nation, it certainly raises some important questions. In fiscal years 2015 and 2016 much of Iowa State University's funding came from a relatively small number of corporations with close to half its sponsorship provided by industry. The fact that certain departments received between 60 and 85% of funding from corporations and trade associations may warrant further scrutiny of funding for university agricultural research. The scientific community commonly views scientists affiliated with research universities as "independent researchers." Yet, funding patterns at Iowa State University suggest that like scientists who are employed by industry, certain university researchers who accept corporate and trade association grants may potentially be subject to conflicts of interest. These conflicts of interest may not be readily apparent as author affiliations simply list the names of universities. Determining the sources of grant money is complicated and sometimes impossible as my difficulty in obtaining specific funding information for the nine out of the ten universities I contacted illustrates.

Scientists who receive industry sponsorship may do everything in their power to conduct their research in an unbiased manner; however, corporate sponsorship creates the possibility of generating a conflict of interest for those studying genetically modified crops produced by a specific company. Industry funding can present a very difficult situation for scientists who fear they will lose access to resources in the future if the results of their studies are unfavorable for the trade associations and corporations responsible for providing grants. It is important to note that even if the impacts of conflicting interests on individual studies conducted by scientists affiliated with research institutions initially appears to be fairly minimal, many small biases may amount to significant biases in published scientific findings. This is especially true if companies have a say in research design or the interpretation of results.

When an academic department receives more than half of its funding from corporations and trade associations, the entire department's research priorities as well as their experimental design and interpretation of data may begin to reflect business interests (Lotter 2009; Peehaus 2010). This may leave less room for research into the potential detrimental impacts of genetically modified crops and associated herbicides and pesticides (Bressler 2009; Krimsky 2015). As set forth in chapter five, for scientists who decide to publish studies that raise concerns about GMOs despite the possibility of challenges from industry, the path is not always an easy one.

Chapter 5: A Case Study: Ignacio Chapela, David Quist, and Mexican Maize

In 1998, the College of Natural Resources at the University of California Berkeley formed what they referred to as a “strategic alliance” with a Swiss agribusiness company called Novartis (Novartis and Zeneca Agrochemicals merged in 2000 to form Syngenta, one of the world’s largest agribusiness and chemical companies) (Scott 2003). This “strategic alliance” provided the Department of Plant and Microbial Biology at Berkeley with a $25 million research grant and gave Novartis control of licenses on about one third of the department’s discoveries (Scott 2003). It also allowed Novartis scientists to fill two of the five seats on the Department of Plant and Microbial Biology’s research committee (Press and Washburn 2000).

Shortly after the formation of this alliance, graduate students at the university formed a group called Students for Responsible Research and circulated a petition calling the alliance between Berkeley and Novartis a “direct conflict with our mission as a public university” (Press and Washburn 2000). Berkeley's student newspaper, the *Daily Californian*, published a series of articles discussing the privatization of the university (Press and Washburn 2000). A coalition of public interest groups later sent a letter to Robert Berdahl, Berkeley's chancellor, and expressed concern that the alliance "would disqualify a leading intellectual center from the ranks of institutions able to provide the kind of research [that is] free from vested interest" (Press and Washburn 2000). Gordon Rausser, the dean of the College of Natural Resources, responded to unease among students and professors by sending a message to all university professors requesting that they refrain from speaking to the press and asking that they direct all concerns to Berkeley’s public-relations office (Press and Washburn 2000). In an interview with *The Atlantic*, Rausser commented that he felt scientific research at Berkeley is, “enhanced, not diminished, when we work creatively in collaboration with other institutions, including private companies" (Press and Washburn 2000). Later, in an article in the Berkeley alumni magazine, Rausser stated that, "Without modern laboratory facilities and access to commercially developed proprietary databases [...] we can neither provide first-rate graduate education nor perform the fundamental research that is part of the University's mission" (Press and Washburn 2000). Rausser felt that some faculty's disapproval of the Novartis alliance might be reflective of their ignorance of the reality of funding patterns in research universities (Press and Washburn 2000).

Rausser's argument regarding the necessity of private funding may have merit considering the inadequacy of public funding. Despite his reassurances about the Novartis alliance, many of Berkeley's faculty remained unconvinced. In 2000, the university conducted a survey and found that 41 percent of faculty supported the alliance (Scott 2003). However, 50 percent feared it would have "negative" or "strongly negative" impacts for academic freedom (Scott 2003). Sixty percent of the faculty expressed concern that the alliance would impede the free exchange of ideas among scientists in the College of Natural Resources.

Ignacio Chapela, a microbial ecology professor and the chairman of the College of Natural Resources' executive committee was very critical of the "strategic alliance" (Press and Washburn 2000). Chapela was no stranger to partnerships between scientists and industry. In fact, he spent three years in Switzerland working for Novartis before coming to Berkeley (Scott 2003). In a 2000 interview with *The Atlantic*, Chapela commented that, "I'm not opposed to individual professors' serving as consultants to industry. If something goes wrong, it's their reputation that's at stake. But this is different. This deal institutionalizes the university's relationship with one company, whose interest is profit. Our role should be to serve the public good" (Press and Washburn 2000). It would not be long before Chapela saw for himself exactly what types of consequences scientists who threatened the profitability of genetically modified crops could face.

In 2001, Chapela and his graduate student David Quist conducted a study regarding the cross-pollination of genetically modified corn with indigenous corn. They found that genetically modified corn exported from the United States had contaminated the native corn grown in Oaxaca, Mexico (Lotter 2009; Peekhaus 2010). Chapela and Quist's finding also suggested that genetically modified DNA could be transferred to offspring (Lotter 2009; Peekhaus 2010). Mexico possesses the largest genetic variation of corn of any country in the world, and the nation banned the cultivation of genetically modified corn in 1998 (Scott 2003). Chapela and Quist's discoveries were particularly significant because they suggested the possibility that exported genetically modified corn was impacting the biodiversity of the Oaxacan corn (Lotter 2009; Peekhaus 2010).

The two scientists published their finding in *Nature*, the world's most cited scientific journal, and shortly after publication, a series of posts appeared in a listserv run by AgBioWorld. The posts referred to the two scientists as "fear-mongering activists," suggested that their endeavors were an attack on "biotechnology, free trade, intellectual property rights and other politically motivated agenda items," and recommended that scientists contact *Nature* and attempt to overwhelm the journal with requests for the retraction of the study. (Matthews 2002: 30). AgBioWorld has been associated with Bivings Group, a public relations firm in Washington, D.C. (Fagan, Traavik, and Bøhn 2015). Bivings Group has worked for Monsanto (Fagan, Traavik, and Bøhn 2015). Jonathan Matthews, a columnist for the *Ecologist*, later traced the comments on AgBioWorld to a Bivings Group computer server and a Monsanto computer server (Lotter 2009; Peekhaus 2010).

Shortly after these comments were posted in AgBioWorld, headlines expressing doubt about Chapela and Quist's study began to circulate in British and American media (Lotter 2009). *Nature* then contacted Chapela and Quist to ask for a response to critical letters they had received and to request additional data (Bressler 2009; Lotter 2009). Chapela and Quist responded with the data, and *Nature* assembled a committee of three to decide whether that study should be retracted. Although two of the committee members supported keeping the article, one of the three committee members recommended that the article be disavowed (Bressler; Lotter 2009; Peekhaus 2010). *Nature* ultimately choose to disavow the articles stating that:

> In light of these discussions and the diverse advice received, *Nature* has concluded that the evidence available is not sufficient to justify the publication of the original paper. As the authors nevertheless wish to stand by the available evidence for their conclusions, we feel it best simply to make these circumstances clear, to publish the criticisms, the authors' response and new data, and to allow our readers to judge the science for themselves. (Metz and Fütterer 2002: 601)

Following *Nature*'s decision, the controversy over the original study and its disavowal continued.

For many scientists, *Nature*'s choice to disavow the article raises questions. Although *Nature* stated that, "the evidence available is not sufficient to justify the publication of the original paper," the journal does not explain why the article was originally published and why the insufficiency of evidence did not originally present an obstacle to its publication. Critics of Chapela and Quist's study suggest that it should be discredited due to methodological errors (Kaplinsky 2002; Worthy, Strohman, and Billings 2002). However, the article underwent a rigorous process of peer-review prior to publication in one of the world's most prestigious scientific journals. In a letter to the editor of *Nature*, a group of Berkeley scientists and scientists from other universities asked, "If the interpretation of the results proposed by the authors of the original paper was judged by *Nature* to be sufficiently erroneous to warrant this editorial statement, why did *Nature* publish the report in the first place?" (Suarez 2002: 1). Some scholars feel that *Nature* was influenced by pro-industry criticism of the article (Bressler 2008; Lotter 2008; Peekhaus 2010; Ross 2004; Suarez 2002). This is especially true if we consider the fact that the article passed peer review by a highly competitive scientific journal prior to publication.

Additional publications questioned the motives of scientists on both sides of the debate regarding genetically modified maize contamination. Food First, also known as the Institute for Food and Development Policy, a non-profit organization focused on global hunger alleviation, published a statement signed by 144 environmental and anti-GMO groups that expressed criticism of industry affiliated scientists' responses to Chapela and Quist's study. It stated that:

> Pro-industry academics are engaging in a highly unethical mud-slinging campaign against the Berkeley researchers. Given the stakes, the biotech industry's desperate attempts to cloud and confuse the scandal is not surprising [...]We call upon Academia and the Private Industry to renounce the use of intimidatory tactics to silence potentially 'dissident' scientists. We call upon the scientific community to publicly support the academic freedom of scientists whose studies conflict with the interests of industry. (Food First 2002: 1-2)

In response to Food First's suggestion that criticisms of Chapela and Quist's were motivated by vested-business interests, AgbioWorld responded with their own statement signed by more than one hundred scientists (AgBioWorld 2002). AgbioWorld's statement asserted that Chapela and Quist may have had a conflict of interest stating that their "point of view was driven by politics and activism, rather than science" (AgBioWorld 2002: 1). Nick Kaplinksy, a professor of Plant and Microbial Biology at the University of California Berkeley, also suggested that Chapela may have conflicts of interest noting that, "Chapela is a board member of PANNA, an advocacy group opposing genetically modified organisms" (Kaplinsy 2002: 1). Furthermore, it is possible that Chapela may have held a grudge against, Novartis (now Syngenta), his previous employer.

Although Chapela's work may certainly have had political and ideological as well as scientific motivations, Chapela and Quist's potential conflicts of interest and those of their critics are quite different. PANNA, the Pesticide Action Network of North America, is a non-profit organization focused on protecting public health and the environment. Monsanto and Syngenta are the first and third largest seed companies in the world. The former controls 23% of the world's proprietary seed market while the later controls 9% (GMWatch 2009). As a public interest organization that relies on charitable donations PANNA is unlikely to be harmed by the publication of scientific findings in either direction. It seems improbable that Chapela would have benefited financially from releasing a scientific study, and Chapela does not rely on support from the organization in order to conduct his research. However, the University of Berkeley did in fact rely on support from Novartis, and without support from the corporation much of their research would be impossible. Furthermore, findings suggesting that genetically modified crops could alter the biodiversity of Mexican maize posed a direct threat to Novartis's product. While Chapela's involvement with PANNA may have motivated his research in a specific area, scientific inquiry into the safety of genetically modified crops can never be conducted in a completely disinterested manner. The economic stake that Novartis, and now Syngenta, have in the ongoing debate on genetically modified crops is simply incomparable to that of PANNA.

Pro-industry scientists did not entirely end the debate on Chapela and Quist's research; however, they successfully cast doubt upon it. This doubt is enough to protect agricultural biotechnology business interests for the time being. Despite the disavowal of their article, further evidence supports Chapela and Quist's study (Peekhaus 2010; Scott 2003). Studies conducted by the Mexican Ministry of Environmental and Natural Resources suggest that GMO "contamination" had occurred as scientists found genetically modified maize in fifteen of the twenty two locations they tested in Oaxaca and nearby Puebla (Scott 2003). Chapela obtained five Mexican studies suggesting that genetically modified corn has contaminated native corn; however, he remains unable to find a scientific journal that will publish this evidence (Peekhaus 2010). When asked about the implications of events following the publication of his study, Chapela commented that, "they have made an example of me. Other scientists see this and decide that maybe they should go back to studying the bristles on the back on a bug" (Ross 2004: 21). Scientists note that the agricultural biotechnology industry not only impacted opinions regarding this specific study, it also created an environment in which information that threatens private interests cannot be disseminated without fear of retaliation (Bressler 2008; Lotter 2008; Peekhaus 2010; Ross 2004). Chapela and Quist would not be the last scientists to face industry criticism for publishing research suggesting that genetically modified crops might prove to have negative consequences.

Chapter 6: A Case Study: Séralini et al., Roundup, and Genetically Modified Maize

In September of 2012, a team of scientists from the University of Caen and the University of Verona led by Gilles-Eric Séralini published the results of a two-year animal feeding study in *Food and Chemical Toxicology* (Loening 2012). The study investigated the health impacts of genetically modified maize NK603 (a type of genetically modified maize manufactured by Monsanto) and two varieties of Roundup (also called glyphosate, a type of insecticide manufactured by Monsanto) (Resnik 2015). The scientists divided the rats into ten groups. In addition to being fed conventional maize, three groups were fed differing amounts of genetically modified maize NK603, three were fed differing amounts of genetically modified maize NK603 with Roundup, and three were given water that contained differing amounts of Roundup (Resnik 2015). The researchers used the final group of rats as the control. The paper reported that the rats in the treated groups had more tumors at the end of the study than the rats in the control group (Resnik 2015). Furthermore, more of the rats in the treated groups had died by the end of the study, and the rats in the treated groups died more rapidly than those in the control group (Jany 2012; Arjó et al. 2013). The difference between the treated group and the control group was more pronounced in the female rats than in the male rats (Jany 2012; Arjó et al. 2013).

Just hours after the article's publication, an intense debate regarding the validity and the potential implications of the study ensued (Fagan, Traavik, and Bøhn 2015). A portion of this debate involved discussion among scientists who were asking clarifying questions regarding the study (Fagan, Traavik, and Bøhn 2015). Scientists expressed concern about Séralini et al.'s experimental design, the experiment's sample size, and the fact that the Sprague-Dawley rats used in the study are predisposed to develop spontaneous tumors (Jany 2012; Arjó et al. 2013). Although some of Séralini et al.'s critics were simply hoping to gain a more complete understanding of the methodology and the potential limitations of the study, others had a vested interest in silencing the safety concerns presented by the published findings.

It was not long before Agbioworld, a major agricultural biotechnology website with long-standing connections to industry, began to assemble petitions with criticisms of Séralini et al.'s study, and more than 700 scientists signed such petitions (Agbioworld 2012). Amid the ongoing debate regarding Séralini et al.'s study, *Food and Chemical Toxicology* created a new position for an Associate Editor for Biotechnology (Resnik 2015). The journal hired Richard Goodman, a past Monsanto employee, to fill the position (Fagan, Traavik, and Bøhn 2015). In addition to working for Monsanto, Goodman had been associated with a non-profit organization called the International Life Sciences Institute (ILSI), which has received funding from the tobacco industry in the past (Fagan, Traavik, and Bøhn 2015). The World Health Organization (WHO) banned the ILSI from participation in the setting of safety regulations because "ILSI was used by certain tobacco companies to thwart tobacco control policies" (WHO 2001: 1). As a result of Goodman's previous experience, there was reason to believe that he would support pro-industry scholarship as an editor for *Food and Chemical Toxicology*.

Shortly after Goodman was hired, the journal asked Séralini and his colleagues to submit all of the raw data used in their study for further review. As associate editor of biotechnology, rather than Editor-in-Chief, Goodman was unable to access Séralini et al.'s data; however, he was involved in the process of review conducted by the journal. When the review process was complete Séralini and his colleagues received a notice stating that their study was to be retracted from *Food and Chemical Toxicology* (Resnik 2015). The retraction notice stated:

> Unequivocally, the Editor-in-Chief found no evidence of fraud or intentional misrepresentation of the data [...] Ultimately, the results presented (while not incorrect) are inconclusive, and therefore do not reach the threshold of publication for *Food and Chemical Toxicology* [...] The editorial board will continue to use this case as a reminder to be as diligent as possible in the peer review process. (*Food and Chemical Toxicology* 2013: 1)

After the retraction of the study, the heated debate regarding the implications of Séralini et al.'s study continued. In fact, many scientists published independent articles evaluating the study's results in which they criticized either the study itself or the process that had led to its retraction (European Food Safety Authority 2012; Jany 2012; Loening 2012; Arjó et al. 2013; Fagan, Traavik, and Bøhn 2015; Resnik 2015; Xia et al. 2015).

One of the many articles expressing criticism of the study suggested that Séralini may have a conflict of interest because he received funding from organizations that had campaigned against genetic engineering in the past (Jany 2013). Séralini received funding from the Association of CERES, "Fondation Charles Leopold Mayer pour le progress de l'homme" (the

Charles Léopold Mayer Foundation for Human Progress, abbreviated FPH), and CRIIGEN (Jany 2013). CERES is a think tank that specializes in agricultural research, FPH is an independent Swiss foundation that provides research grants that "contribute to human progress" through science and social development," and CRIIGEN is "a Committee for Independent Research and Information on Genetic Engineering" (CERES 2016; CRIIGEN 2016; Fondation Charles Leopold Mayer pour le progress de l'homme 2016). The author suggesting Séralini's potential conflict of interest does not explain how any of Séralini's sponsors could have benefited financially from the results of Séralini's study, and therefore it remains difficult for the reader to determine whether Séralini did in fact have a conflict of interest (Jany 2013).

The European Food Safety Authority (EFSA) also published a review of Séralini et al.'s study. This review stated that, "EFSA concludes that the Séralini et al. study as reported in the 2012 publication does not impact the ongoing re-evaluation of glyphosate, and does not see a need to reopen the existing safety evaluation of maize NK603 and its related stacks" (EFSA 2012: 1). From their statement, it is unclear exactly why the EFSA does not plan to continue examining the safety of maize NK603. Although Séralini et al.'s study was inconclusive, it highlights the possibility of potential health risks posed by both glyphosate and maize NK603. Therefore, some scientists felt it was surprising that a food safety authority saw no cause for further evaluation of the insecticide and the genetically modified corn (Robinson et al. 2013; Wickson and Wynne 2012).

The EFSA's conclusion that no further safety testing is warranted may in fact be explained by a conflict of interest (European Parliament 2012). In 2012, the same year the EFSA published their statement evaluating Séralini et al.'s study, the European Parliament refused to approve the EFSA's budget. On April 4, 2012 the European Parliament published a report stating that:

> In September 2010 the Chair of the Management Board [of the EFSA] was reported to have direct links to the food industry, and to be a member of the Board of Directors of the International Life Science Institute (ILSI) [...] While a dialogue with industry on product assessment methodologies is legitimate and necessary, this dialogue should not undermine the independence of the Authority nor the integrity of risk assessment procedures; [the European Parliament] asks [...] the Authority to consider as a conflict of interest the current or recent past participation of its Management Board, panel and working group members or staff in ILSI activities such as task forces, scientific committees or chairs for conferences. (European Parliament 2012)

This occurrence illustrates how private interests have impacted safety testing procedures not only among scientists at research universities, but also within government-funded agencies that citizens tend to trust. The EFSA's statement regarding Séralini et al.'s study carried a great deal of weight because many regarded its opinion as the final word on the topic (Kuntz 2012; Robinson et al 2013). The discovery of the EFSA's links to the food industry highlights the extent to which conflicts of interest can alter the opinion of both scientists and the public.

Séralini and the team of scientists with whom he worked felt that criticisms of his study were largely based upon protecting private interests rather than concern over the study's methodology and conclusiveness. In response to the criticisms they received, Séralini et al. wrote a letter to the editor of *Food and Chemical Toxicology* stating that:

> 75% of our first criticisms arising within a week, among publishing authors, come from plant biologists, some developing patents on GMOs, even if it was a toxicological paper on mammals, and from Monsanto Company who owns both the NK603 GM maize and Roundup herbicide. Our study has limits like anyone, and here we carefully answer to all criticisms from agencies, consultants and scientists, that were sent to the Editor or to ourselves. At this level, a full debate is biased if the toxicity tests on mammals of NK603 and R obtained by Monsanto Company remain confidential and thus unavailable in an electronic format for the whole scientific community to conduct independent scrutiny of the raw data. (Séralini et. al 2013)

While questions regarding Séralini et al.'s study are certainly warranted, the percentage of criticisms coming from scientists and organizations with connections to the agricultural biotechnology industry raised concerns for some scientists (Jany 2012; Loening 2012; Arjó et al. 2013; Fagan, Traavik, and Bøhn 2015; Resnik 2015; Xia et al. 2015). The raw data of Séralini et al.'s study was available for scientists to examine while Monsanto's safety testing data remained confidential (Fagan, Traavik, and Bøhn 2015). Regardless of the conclusiveness of Séralini et al.'s study, differences in the possible level of scrutiny of their study and that conducted by Monsanto represent a double standard that privileges industry affiliated scientists (Jany 2012; Loening 2012; Arjó et al. 2013; Fagan, Traavik, and Bøhn 2015; Resnik 2015; Xia et al. 2015).

Despite widespread criticism of Séralini et al.'s study, many scientists agreed that its retraction underscored industry's influence on *Food and Chemical Toxicology* (Arjó et al. 2013; Fagan, Traavik, and Bøhn 2015). Dr. Andrea Rosanoff, the director of the Research and Science Information Outreach at the Center for Magnesium Education and Research, wrote a letter to the journal expressing her concerns about bias in the process leading to the study's retraction:

> The retraction of the Séralini et al. article is an extraordinary event, especially a whole year past publication. It seems that the post-publication review is not in agreement with the pre-publication review. I believe that in order to preserve and protect the journal's scientific integrity (as well as the integrity of your vitally important peer-reviewed publication process) that you should publish the raw data you obtained from the Corresponding Author with the post-publication reviewers' analysis of why the results were ''inconclusive.'' That way the scientific community can comment and discuss the post-publication reviewers' analysis and decision, and criticisms of ''bias'' can be thwarted. It is the only way to ensure ''bias'' was not at work in the decision of the journal's editorial board. (*Food and Chemical Toxicology* 2014)

Rosanoff's letter highlights some important issues. *Food and Chemical Toxicology*'s retraction raises the question of why the journal published the article in the first place if the data provided by Séralini et al. was in fact too inconclusive to pass peer review. The previously discussed data supports the notion that *Food and Chemical Toxicology* has strong industry ties. My sample contained 26 articles from *Food and Chemical Toxicology*, and in the case of half of these articles one or more authors of peer-reviewed studies worked for industry. Furthermore, one of the four co-editors of the journal works for Dupont (*Food and Chemical Toxicology* 2017). Some scientists felt that industry affiliated criticism of the Séralini et al. study, rather than inconclusiveness or methodological shortcomings, played a significant role in the retraction of the study (Fagan, Traavik, and Bøhn 2015; Martinelli, Małgorzata, and Siipi 2013; Resnik 2015; Robinson, Latham, and Smith 2013).

In 2014, Séralini et al.'s study was republished in a different journal called *Environmental Sciences Europe*, suggesting that despite its shortcomings the study still met the rigorous standards required for publication in a scientific journal (Fagan, Traavik, and Bøhn 2015). By retracting Séralini et al.'s raw data entirely, certain scientists felt that *Food and Chemical Toxicology* attempted to limit further dialogue regarding the study (Fagan, Traavik, and Bøhn 2015; Resnik 2015; Robinson, Latham, and Smith 2013). Even if Séralini et al.'s data had been inconclusive, it was still a valuable addition of to the body of studies on safety testing (Fagan, Traavik, and Bøhn 2015; Robinson, Latham, and Smith 2013). Some scientists note that the journal's decision to attempt to prevent widespread access to Séralini et al.'s data functioned to impede future scientific inquiry regarding the safety of Roundup and genetically modified maize and to restrict the dissemination of certain scientific knowledge (Fagan, Traavik, and Bøhn 2015; Resnik 2015; Robinson, Latham, and Smith 2013).

Industry's involvement in agricultural biotechnology research has contributed to a situation in which vehement opposition to scientific findings may begin to obscure the actual issues that these discoveries raise (Loening 2012; Scott 2003). Some scientists feel that because of so many potential conflicts of interest, it has become difficult to determine which critiques are based on genuine concerns about research design and which are an attempt to protect vested business interests (Loening 2012; Martinelli, Małgorzata, and Siipi 2013). The chaotic arguments around Séralini et al.'s study highlight science's failure to resolve controversies when debates have such high political and economic stakes. When science can no longer settle these types of debates, policy implementation may privilege the scientists with the most political and economic backing rather than those with the most convincing evidence.

The contentious debates surrounding Séralini et al.'s study functioned to prevent, rather than encourage, further examination of the safety of genetically modified crops (Fagan, Traavik, and Bøhn 2015; Loening 2012; Martinelli, Małgorzata, and Siipi 2013; Resnik 2015). The reactions of certain industry affiliated scientists have discouraged other scientists from conducting safety testing, ultimately preventing scientific progress in some areas of genetically modified crop research (Lotter 2008; Peekhaus 2010). At present, scientific research on genetically modified crops fits the definition of "misbehaving science" presented by the sociologist of science Aaron Panofsky. Misbehaving science is "a situation where boundaries between science and nonscience cannot be drawn...If science is like a machine for resolving controversies, in misbehaving science that machine is broken" (Panofsky 2014: 9). The discourse around Séralini et al.'s study illustrates what Scott refers to as "an acute breakdown in scientific discourse" (Scott 2003: 569). The scientific discourse on GMOs is far too important to be impeded by the current polarization and frequent animosity between scientists with differing perspectives.

Conclusion

The dialogue around genetically modified crops has become a rather hostile one, and in many cases the focus has shifted toward winning an argument rather that finding evidence-based answers and learning from scientists who present different opinions (Böschen 2009; Krimsky 2015). As Dave Goulson, a biology professor at the University of Sussex stated in an interview with the *New York Times*, "You can't win. If you are funded by industry, people are suspicious of your research. If you're not funded, you're accused of being a tree-hugging greenie activist" (Hakim 2017). The antagonistic nature of the debate on genetic modification is largely inevitable given the extremely high financial stakes it presents. However, such confrontational interactions between opposing groups of scholars ultimately impede necessary cooperation and discourage further research into controversial topics. Working to establish more cordial communications between scientists may enable more nuanced discussions between experts and promote new research endeavors.

In some instances, debates on genetically modified crops may reflect differences in political opinions (Kinchy 2012). If genetically modified crops prove to present risks, new regulations will likely be implemented restricting the use of genetically modified seeds or requiring labeling of GMOs. Conservatives who tend to oppose government regulations may be more supportive of genetically modified crops than liberals who believe more stringent regulations are necessary in the face of scientific uncertainty (Kinchy 2012). In the presence of scientific ambiguity, business interests and political perspectives have become entangled with scientific discourse, and drawing the boundaries between evidence-based science and ulterior motives has become increasingly difficult (Böschen 2009; Krimsky 2015).

The existence of a conflict of interest alone does not necessarily compromise the integrity of scientific research; however, the high prevalence of studies containing conflicts of interest may prove to be problematic. Inaccurate or missing conflict of interest statements may make it difficult for policy makers as well as scientists and consumers to discern which studies are reliable. The relatively high prevalence of conflicts of interest, as well as the failure of certain authors to disclose conflicts of interest, threatens to undermine public trust in peer-reviewed scientific studies on GMO safety as well as other salient topics.

As private sponsorship for research continues to increase, measures to limit the prevalence and the impacts of financial conflicts of interest will prove to be beneficial for both scientists and public audiences (Steinbrook and Lo 2012; Zonia 2016). Some proposed strategies for managing financial conflicts of interest include limiting interactions between university faculty members and industry representatives, creating more robust systems of oversight within existing offices of sponsored research, and reforming policies regarding who is allowed to serve on the editorial boards of journals (Schwartz et al. 2008; Steinbrook and Lo 2012). Many of these approaches may be unpopular, expensive, and logistically complicated (Steinbrook and Lo 2012). However, recognition of and honest dialogue around the challenges presented by conflicts of interest are necessary.

Improving transparency in published research on genetically modified crops may also be advantageous, as it would allow readers to identify sources of possible bias (Brennan et al 2006; Schwartz et al. 2008; Steinbrook and Lo 2012). Requirements regarding funding disclosure give the public more insight into potential conflicts of interests. Nevertheless, disclosing funding sources does not eliminate conflicting business interests (Schwartz et al. 2008; Steinbrook and Lo 2012). Disclosure may also have the negative consequence of causing readers to underestimate the potential for biases in publications in which authors have disclosed conflicting interests (Schwartz et al. 2008). Despite its limitations, improved disclosure of research funding is a feasible goal and an important step (Brennan et al 2006; Schwartz et al. 2008; Steinbrook and Lo 2012; Zonia 2016). The absence of a perfect solution need not stand in the way of more modest efforts to improve transparency, manage conflicts of interest, and protect the integrity of published studies.

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