The Flow of Scientific Knowledge from Lab to the Lay Public

The Case of Genetically Modified Food

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This article reports on a study of how scientific knowledge about genetically modified (GM) food flows to the American public, focusing on language and message genres in the scientific literature, newspapers, and popular magazines. A comprehensive search of these literatures from 1992 to 2002 revealed a publishing pattern of scientific communication that contrasted with that found in the lay press. Examination of this difference led researchers to a scientific study on the effect of GM corn pollen on the Monarch butterfly. The case study of the discourse surrounding this event demonstrates how press releases affect what is published in the popular press. The role of this event in generating subtle repercussions in the perceptions of U.S. consumers, similar to the ripple effects found in Kasperson's social amplification of risk theory, is analyzed and reported.

Keywords: *biotechnology; genetically modified food; scholarly publishing; media studies; consumer learning; knowledge development, newspapers; GM food*

The American public has a genuine interest in science, scientific discovery, and results of experimental research in industrial and academic laboratories because lay people have a critical stake in how experimental results affect their health, personal economy, and quality of life (Hart 2002; Priest 2001). Lay people gain knowledge and form opinions about scientific research

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through a number of information and communication channels: newspapers, popular journals, television news broadcasts, radio programs, and the Internet. Mass media may not affect public opinion in a strong, direct way, but throughout the long term, news media do exert influence on what people think (Priest 1995). From another perspective, the media reflect and report on the pulse of the public—the common knowledge of the day and the controversies and concerns of everyday people. As Retzinger and others maintain, "The media plays an increasingly important role in providing consumers with information about current agricultural practices and their bearing on the foods we eat every day. Such information may be especially important with respect to GM foods" (2001, 1).

By some reports, many Americans have little awareness of genetically modified (GM) food, even though GM foods are commonly used in packaged food products and in agricultural practices (Hallman et al. 2002; Pew Initiative on Food and Biotechnology 2003). In the recent past, despite their lack of knowledge of GM foods, Americans who were aware of biotechnology research generally thought of it as positive, even when genetically modified food was concerned (Ten Eyck, Thompson, and Priest 2001). The positive views of the U.S. public have been in approximate alignment with stories about genetic engineering that appeared in the U.S. media from 1997 to 1999. Most of the articles were framed in a positive light toward genetic experimentation, although there were slightly more negative stories on agricultural and food genetic engineering than on other biotechnology topics like animal cloning, stem cell research, and the like (Ten Eyck, Thompson, and Priest 2001).

American opinion is almost equally divided on approval and disapproval of GM foods; the U.S. public is, however, somewhat less positive toward plant-based GM foods than they were in 2001. In a large national study in

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which 1,021 adults in 48 states were interviewed, Americans reported that they knew little about GM food, and survey questions testing their knowledge showed that they were right (Hallman et al. 2003). This article reports on an effort to track written materials that could inform the American public and increase their knowledge of GM foods and an in-depth case study of the Monarch incident, a scientific study about GM corn that influenced the increase in published stories about GM food and amplified the public's perceptions of risk to living organisms.

Background: The Controversy in the United States and Abroad

Genetically modified food, also known as biotechnology food, is a relatively new phenomenon for the lay public; its profile has risen, however, since it became the subject of trade wars between the United States and Europe in 2003. Terms differ from context to country,[1] but essentially genetically modified crops produce food that has been created by splicing the gene from one organism into another organism (often a nonrelated species), creating a new food product (Anderson 2000; Cummins and Lilliston 2000; Lurquin 2002; Priest 2001). For example, a gene may be transferred into a tomato cell that will effectively produce a tomato that will stay firm for weeks on a grocery store shelf (Martineau 2001), rice can be modified to contain a precursor to vitamin A (Hart 2002), or cow genes can be engineered to produce pharmaceuticals in milk (Pollack 2001). Today in the United States, most of the soybeans and about a third of the corn planted are genetically engineered, yet most Americans are either unaware of the GM food controversies or are ambivalent about their common use by farmers and in packaged food products (Hallman et al. 2002; Hart 2002).

In the debate about biotechnology safety, many Europeans are generally opposed to GM food (Gaskell et al. 2001a), whereas most Americans have more favorable perceptions of biotechnology (Gaskell et al. 2001b). This may be an oversimplification of a complex issue; nevertheless, the Eurobarometer used to study perceptions of citizens of the European Union has shown that Europeans think that there is more risk to eating GM foods than do North Americans (Gaskell et al. 2001a).

In the United States, the controversy is not as highly charged as in the European Union. Some American scientists, federal officials, and industry representatives maintain that GM foods are quite safe, while other scientists and some consumer advocacy groups, organic food industry representatives, and environmental organizations insist that there are serious risks and

dangers in growing and ingesting such foods (Gaskell et al. 2001b; Lurquin 2002; Martineau 2001). There is mounting evidence that even though many scientists are confident that GM food is safe, they haven't made their case to the public using solid scientific findings. In a study of 20 years' worth of news items on GM foods ($n = 1{,}524$), Retzinger found that there were four times as many news items in English-language international news sources as in the U.S. press (2001, 5). Although Retzinger did not make a cause-and-effect argument related to the number of media stories published and what Americans know about GM foods, she does state that the media have a critical role to play in setting the agenda for the debate.

When the Clinton administration's Secretary of Agriculture Dan Glickman left office, he warned the incoming secretary, Ann Veneman, that GM food would be one of the thorniest issues she would have to manage. Glickman told the press, "Biotechnology is going to be thrust on her, as Dick Cheney would say, big time . . . like it was on me, big time" (quoted in Lambrecht 2001, paragraph 6). One irony of Glickman's warning is that Veneman served on the board of Calgene, a company owned by Monsanto, one of the biggest producers of GM foods in the world. As she took up her new office, Veneman said, "The hard-working men and women who provide our food and fiber have been tested by low prices, bad weather and other adversities," (Lambrecht 2001, paragraph 10), possibly referring obliquely to GM food as another "adversity" that will test the country's farmers.

Genetically modified food may, indeed, be a hard test for American agriculture, even though there might be productivity and economic advantages to raising biotech crops (Pinstrup-Andersen and Schioler 2000). Genetically engineered food has become one of the most controversial agricultural topics to emerge in recent years and may hurt the American farm economy through limited imports of American grain, fruits, and vegetable products by the European Union and some countries in Africa (Alvarez 2003; Becker 2003b). The George W. Bush administration's top trade official, Robert B. Zoellick, announced that he has lost his patience about the safety issue regarding American GM food (Becker 2003a). Zoellick has spoken harshly about African and European nations who have refused to accept American food based on the questionable safety of corn and soybeans that have been genetically modified, and in May 2003, he filed an injunction against the World Trade Organization regarding the European Commission's decision to refuse to accept GM food from the United States (Becker and Barboza 2003).

In comparison to their European counterparts, the American public has remained relatively silent regarding the issue of GM food. Why are Americans ambivalent and even unaware about GM foods? Perhaps, taking the cue from trade representative Zoellick, their loyalty to their country as the

"breadbasket of the world" leads them to be less critical of technological advances in agriculture. Americans are more optimistic about technological products in general, and they view technological developments in the favorable light of progress. In their study of work and the strategies that people use to feel ethical and proud about the work they do, Gardner, Csikszentmihalyi, and Damon point out how Americans differ from others in how they view technological change: "With change so rapid, it may be difficult—particularly for Americans, who are enthralled by change—to pause and reflect on possible consequences. There may also be a naïve faith that technology in itself can solve problems" (2001, 60).

The U.S. public may need more factual information on studies that show GM food to be safe to eat and to grow, said Belinda Martineau (2001), a former scientist at Calgene, the company that developed the genetically modified Flavr Savr tomato. Martineau maintains that much of the "food fight" about GM foods could be resolved if the scientific community gave the public hard facts about tests that have proven that the foods are safe for eating and not harmful to the environment. Instead, these facts are usually buried in scientific publications and seldom made available to consumers, she claims (Martineau 2001).

Others disagree, claiming that lack of information is not the problem. Priest (1995) points out that in the public marketplace of ideas, the lay public needs more than the positivist "rationalist perspective" usually provided by universities and industrial research and development representatives. They need the subjectivist view as well to make informed decisions about ethical choices and risk behavior (Priest 1995). Science journalists can provide forums for discussions about value judgments, ethical considerations, and an understanding of an issue within the context of a social milieu that can inform the public and provide the underpinnings for a democratic dialogue on issues like creating, harvesting, and consuming GM food, Priest maintains. The amount of information written and consumed may not provide the total picture for consumer behavior, but knowing the information landscape can offer understanding and provide the foundation for constructing common knowledge. Scientific literature and lay press accounts that provide this information will be examined in the next section of the article.

Scholarly Scientific Literature and the Popular Press

This article reports on an investigation of how scientific knowledge flows to the public through published articles in science journals, press releases, and the lay press. People's opinions and perceptions and their subsequent

decision making on consumer goods are related to what they know, so it is important to understand where and how the public accesses information and acquires new knowledge. The first phase of an international research study focused on the topic of GM food and how the topic is treated in science journals and in the popular press. The project examined the language used by science writers, journalists, and publicists. Electronic versions of scientific journal articles and articles published in the popular press during 1992-2002 were retrieved and analyzed.[2] An in-depth study of information and knowledge about a particular incident related to genetically modified products—Bt corn[3] and the Monarch butterfly event—is included in this article to demonstrate how press releases, one type of media communication, are used to influence the writing on science subjects in the popular press. The narrative will demonstrate how 1999 was a watershed year for genetically modified food and for the publications that resulted from a number of events. We will show how a short communication about a small laboratory experiment had effects well beyond its own claims, stimulating the public's imagination about a risk event not about humans but about butterflies. As Eldridge and Reilly (2003) explain in relation to mad cow disease, the impact and ripple effects of media stories that recount possible dangers can influence public behavior and even reach the level of stigmatizing an entire industry.

The scientific communities, both academic and corporate, publish scholarly papers for peers, but scientists also use the mass media to popularize scientific findings and ideas (Lievrouw 1990). Media reports, often based on press releases issued by corporate or university researchers through their public relations departments, can help "sell" science or at least heighten awareness of new discoveries. Scientific knowledge and research generally make their way into popular literature when there are risk factors that might affect the general public or when controversies arise. We are interpreting the term *scientific knowledge* to mean those reports of experimental research that appear in the peer-reviewed journals read by scientists, subscribed to by university libraries and by industrial special libraries that cater to research scientists. We will also show developments in the lay press related to GM crops and food that are clear examples of how incidents about potentially harmful foods can be amplified through the media (Eldridge and Reilly 2003; Kasperson, Jhaveri, and Kasperson 2001; Kasperson et al. 1988).

Scholars across disciplines have focused on the channels, frames, and themes used to reach the public on agricultural biotechnology in the popular press (Gaskell et al. 2001b; Priest 1994; Ten Eyck, Thompson, and Priest 2001). Gaskell and Bauer's prodigious edited volume *Biotechnology 1996-2000* (2001) details the press coverage of food biotechnology in essays from various international perspectives. Eldridge and Reilly (2003) studied how

the media reported on mad cow disease in Great Britain by focusing on articles in UK newspapers during a ten-year period. Some projects just use one or two newspaper databases to search for articles, and most often they do not relate news coverage to scholarly scientific publications. Overall, the Rutgers study had a broader and deeper scope and a wider range of publications in the sample, and researchers searched iteratively using the power of Boolean information-retrieval techniques and specific field searching in proprietary electronic sources to hone the accuracy of results. The sample of literature used in the study included scholarly scientific journal articles in *Agricola*, produced by the National Agriculture Library with material from more than 2,000 journals; *Biosis Previews*, covering 4,900 journals in which research in biological and agricultural sciences is published; *CAB Abstracts*, with material from more than 14,900 scholarly journals reporting on scientific research including agriculture and agribusiness, and *Food Science and Technology Abstracts*, with primary source material from more than 1,900 journals on food science and technology. Lexis-Nexis and Dialog electronic data files were used to survey a broad scope of lay literature published during 1992-2002 in 19 major U.S. newspapers, including the papers of influence, the *New York Times* and the *Wall Street Journal*, and articles in more than 400 popular magazines. Accuracy, precision, and depth in searching are critical to information retrieval because intelligent publication trend analysis is tied to a sample of articles that are substantially relevant to the subject matter. Through cursory searching, one can easily find *false drops* (inaccurate results), that is, articles that might mention GM foods in passing but are essentially about another topic such as public policy, political campaigns, and trade deliberations. Our searches were adapted and revised multiple times to ensure a sample set of relevant GM food articles. See Table 1 for detailed information on the contents as well as producers and information providers of the electronic information sources.

In studying the corpus of published information about genetically modified foods available to the American public, the researchers for this project sought answers to the following questions:

- What is the relationship between articles published in the scientific literature and those published in the general literature?
- What critical incident might provide an exemplar for the flow of scientific knowledge to public knowledge?
- What inferences can we make about the nature of public knowledge by examining publication trends and the material available to the public?
- What effect do language and publication genre have on the public perception of science issues?

TABLE 1
Proprietary Electronic Sources Used for Accessing Information about GM Food

File Name	*Producer and Provider*
Science Literature Files[a]	
Agricola (2,000+ serial titles)	USDA, National Agriculture Library/Dialog
Biosis (4,900+ serial titles)	BIOSIS/Dialog
CAB Abstracts (14,000+ serial titles)	CAB International/Dialog
Food Science and Technology Abstracts (1,800+ serial titles)	IFIS Publishing/Dialog
Lay Literature Files	
Gale Group Magazine Database Indexes and includes information and some full text from more than 400 popular magazines	Thomson Co./Dialog
New York Times Full text of news stories	Lexis-Nexis/Reed Elsevier
PapersMJ (major newspapers) Includes some indexing and full text of news stories from the *Denver Post*, *Arizona Republic/Phoenix Gazette*, *St. Louis Post-Dispatch*, *Detroit Free Press*, *Boston Globe*, *Philadelphia Inquirer*, *Newsday* and *New York Newsday*, *San Francisco Chronicle*, *Denver Rocky Mountain News*, *Miami Herald*, *USA Today*, *Oregonian*, *Atlanta Journal/Atlanta Constitution*, *Sun*, *Christian Science Monitor*, *Plain Dealer*, and *St. Petersburg Times*	Thomson Co/Dialog
Wall Street Journal Full text of news stories	Dow-Jones Information Services

a. Science files include bibliographic information, index terms, and abstracts.

Retrieving Information about Genetically Modified Foods

Methodology

Researchers in private industry and in university settings use professional, proprietary electronic information sources that tend to be more sophisticated, scholarly, and comprehensive in content, indexing, and type of material than Internet sources. In addition to allowing for precision in Boolean searching, a controlled vocabulary, field searching, advanced command language, and searching by both scientific and lay terms, searchers using sophisticated databases can retrieve information from specific years and across multiple databases. In the case of GM food, it was particularly important to be able to search on publications from specific years and to "drill down" in the text because we wanted to examine content and be able to find out why more publications were published in some years rather than others. We were interested in finding out the relationship between critical incidents and publication patterns and if there were one case that influenced the public's perception of GM food in a significant way.

Language Matters: Search Terms, Syntax, and Sources

As in any topic area, the language about genetic technology processes varies in connotation. The connotations are sometimes laced with political overtones, pejorative language, and euphemisms. GM foods can alternately be referred to as *genetically modified (GM)*, *genetically engineered*, *genetically altered*, or *transgenic*, terms that fill press reports and that may actually serve to confuse lay readers because of the number and variety of terms used. When it comes to ingesting a GM product, consumers may wonder about the safety and desirability of putting what is sometimes referred to derogatively as "Frankenfood" on their tables. By examining the language used to identify the topic in a variety of proprietary electronic sources of scientific and popular publications (see Table 1), as well as by analyzing the publishing patterns of stories on GM food, we reached an understanding of the scope and availability of information about this topic accessible to the nontechnically trained general public. By *popular literature*, we mean primarily newspapers and magazines; stories appearing on Internet Web sites and on broadcast media are being investigated in another phase of the project.

Through an examination of the literature and the indexing in retrieved articles, researchers developed a list of keywords that reflect the richness of the

TABLE 2
A Ranking of Indexical Language Most Commonly Used to Identify Information on GM Food, 1992-2002

Genetically modified food[a]
Agricultural biotechnology
Genetically modified crop
Genetically engineered food
Genetically modified organism
GMF
Genetically engineered crop
Genetically altered food
Starlink
Frankenfood
Transgenic food
Genetically altered crop
Ag biotech[b]
GMO[b]

a. Ranked in descending order by number of items retrieved.
b. Not included in results because of ambiguities in the term or insignificant findings.

language used in this field. In contrast to other studies on biotechnology and the media (e.g., Gutteling et al. 2002; Nisbet and Lewenstein 2002; Ten Eyck, Thompson, and Priest 2001), this research focused specifically on biotechnology as it relates to agriculture, crops, and food. Twelve keyword phrases were found to be the ones used most commonly and most often in scholarly papers and media articles, but not all were appropriate for searching. For example, the acronym GMO, or *genetically modified organism*, often refers to genetically modified food, but it also refers to a mutual fund company, so it was rejected as a search term. The full phrase *genetically modified organism* was used, however. *Ag biotech* was dropped because its rare occurrence added little to the analysis. The phrase *transgenic food* was added later because it began to appear in the indexing (keyword) field of some articles. See Table 2 for a complete list of indexical language used for information retrieval.

During the fall of 2002, all the selected data files were searched with the keywords and phrases, allowing for the singular and plural versions of all terms to be included. The following search strategy was used in all the science, news, and magazine databases:

s genetically()modified()food? or genetically()engineered()food? or genetically()altered()food? or transgenic?()food? or starlink or genetically() modified()crop? or genetically()modified()organism? or genetically()engineered()crop? or genetically()altered()crop? or frankenfood? or GMF or agricultural()biotechnology?

This strategy, using some of the terms used by Retzinger (2001), ensured that the exact phrase would be retrieved because the parentheses serve as linking mechanisms, virtually "pasting" the words together in a string. For example, placing the () between *genetically*, *modified*, and *food* guarantees that the terms must be adjacent to each other in the text. This search tactic helps eliminate false drops in the relevant publications chosen by the system. In Dialog, the question mark serves as a wild card or truncation symbol. We used similar search statements in Dow Jones Interactive to retrieve articles published in the *Wall Street Journal*, as well as in Lexis-Nexis, which we used to find the *New York Times* articles, but we adjusted the wild card and changed the way that phrases were connected to accommodate those systems' protocols.

We assumed that by examining the number and type of articles produced during 1992-2002, years when U.S. agriculture was adopting biotechnology and farmers were planting GM foods, publishing trends could be seen and analyzed to examine what information was available from scholarly and popular sources. (See Table 3 for a timeline of notable GM events.) The intention was to be both precise and comprehensive so that private research, academic research, and public opinion and controversy could be traced.

Dialog was chosen as a primary research tool because both science and popular literature are available through the company's large array of content files. The sources included in Dialog files are generally of high quality and provide a relatively consistent method of searching across subject areas. Some capabilities for the advanced searcher are exclusive to Dialog and are just not available in many other database contexts. Through a central index (Dialindex), the files Agricola, Biosis Previews, CAB Abstracts, and Food Science and Technology Abstracts emerged as those that contained the most items about agricultural or food biotechnology. Full-text articles from seventeen major newspapers in the United States were searched through the PapersMJ file, which includes coverage of major U.S. newspapers. The full text from the *New York Times* was searched through Lexis-Nexis, and the *Wall Street Journal* was searched through Dow Jones Interactive. The *New York Times* and the *Wall Street Journal* were chosen because they are papers of record for the United States, they are read throughout the country, and they influence public opinion. Additionally, the *Wall Street Journal* was included because preliminary research showed that the paper provides significant coverage of GM food from the framework of agricultural business.

TABLE 3
Significant Events in the Timeline of the Development of Genetic Modification Technologies

1983	Patents granted to U.S. companies for genetically modified plants.
1987	The first authorized outdoor test of a genetically altered bacterium that inhibits frost formation on strawberry and potato plants.
1990	The first food product modified by biotechnology, an enzyme for cheese production, is approved in the United States.
1993	The U.S. FDA declares that genetically engineered foods are "not inherently dangerous" and do not require special regulation.
1994	The first genetically engineered whole food product, the Flavr Savr tomato, receives U.S. FDA approval.
1996	Bovine somatotropin (bst), designed to increase milk production in dairy cattle, is approved for use in the United States.
	Genetically modified crops grown on nearly 5 million acres worldwide (in Argentina, Australia, Canada, China, Mexico, and the United States).
1996-1997	Soybeans and corn, genetically modified to resist pesticide and insects, are approved for sale in the United States.
1997	Dolly the sheep is the first animal cloned from an adult cell.
1999	Communication in the journal *Nature* shows increased mortality in Monarch caterpillars after eating genetically modified corn pollen.
2000	108.9 million acres of biotech crops in 13 countries.
	Genetically modified corn, approved only for animal consumption, is found in taco shells sold in the United States.
2002	Researchers sequence the DNA of rice, the main food source for two-thirds of the world's population. It is the first crop to have its genome decoded.
	The National Center for Food and Agricultural Policy (NCFAP) study found that 6 biotech crops planted in the United States (soybeans, corn, cotton, papaya, squash, and canola) produced an additional 4 billion pounds of food and fiber on the same acreage, improved farm income by $1.5 billion, and reduced pesticide use by 46 million pounds.

SOURCE: Adapted from Biotechnology Industry Organization (1990), Council for Biotechnology Information (2003), Duke University (2003), and University of Calgary (2003).

Materials from newswire services available in the Dialog file Newswire were searched early on, but the files were dropped from the final analysis because they gave a false impression of the number of stories published about genetically modified food. The main difficulty in using the newswire stories is that all wire stories are not always picked up by newspapers and, therefore, are not available to the public. The researchers were more interested in

popular material that the public might read and that, therefore, might influence their thinking.

Searching and Retrieval Results

The results show that material retrieved included articles, letters to the editor, editorials, and opinion pieces. Numbers were charted per year and source; Dialog has a ranking feature that allows for machine-assisted calculations of items retrieved, but calculations were done by hand for Lexis-Nexis (*New York Times*) and Dow-Jones Interactive (*Wall Street Journal*) data because those two database providers do not have the rank feature. Searches were completed by two different researchers, and results reflect publications from January 1, 1992, to October 31, 2002. Three assumptions guided the searching and subsequent analysis:

- Numbers of items would increase as the years went by.
- Spikes in numbers would be related to newsworthy "events," new scientific discoveries, or major controversies.
- Increases in scientific material would be paralleled by increases in mass media print articles.

Discussion of Results

Publication Patterns

The publishing pattern for articles about genetically modified food changed considerably during the study period from 1992 to 2002. Figure 1 shows clearly that the fewest publications about GM agriculture and food[4] were published in 1995 with slow but steady growth through 1998. In 1999, 2,230 articles were published, and in 2000, there were 2,882 in print, showing that the numbers of articles rose dramatically. Publication levels fell in 2001 (n = 1,994) and 2002 (n = 936).

Compared with items in the popular literature, we found that articles in the scientific literature remained relatively static. For instance, Agricola had 163 articles in 1993 and 128 articles in 1999. Figure 2 shows this effect more clearly by contrasting the number of articles in all science-oriented databases with those in the news media and lay literature. Overall, the science literature shows slow steady growth after 1994, while the popular literature shadows this for several years (1994-1998), and then a big increase in the popular literature occurs in 1999 (n = 1,513). The numbers for the lay literature increased

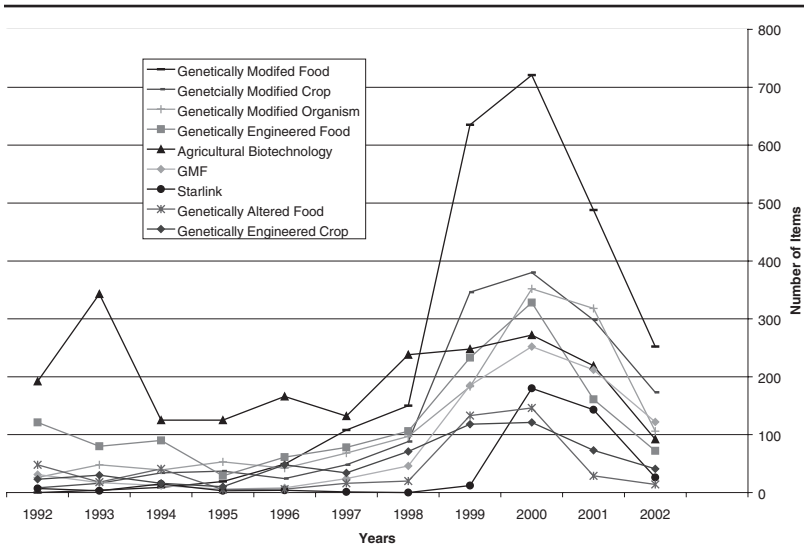

Figure 1: Volume of Publications and Trends in Indexical Language: Scientific and Lay Literature, 1992-2002

again in 2000 with 2,042 items, then dropped sharply in 2001 with only 1,115 items retrieved. The science literature shows a small spike in 2001 as the popular press articles begin to drop off dramatically. The major focus on the attacks on the World Trade Center and the Pentagon in late 2001 did not preclude scientists from continuing to work in the lab producing genetically engineered products. As the press closely follows changing events in the world at large (Nisbet and Lewenstein 2002), it is understandable that in the aftermath of September 2001, stories on food biotechnology took a back seat to the news of terrorist plots and security concerns.

It is natural for the press to cover an issue only when it becomes controversial or when harm is rendered, so it is not surprising that coverage in the popular press changes with the perception of risk on the part of the public and science journalists. Although the research on GM food continued in earnest throughout the 1990s, as documented in the Table 3 timeline, press coverage was minimal until late 1998 and 1999. Popular press articles about the topic were even fewer than those published in the selective peer-reviewed scholarly literature (see Figure 2). In this study of publications about GM food, the press coverage was similar to the coverage of articles in the British media related to bovine spongiform encephalopathy (BSE), or mad cow disease (Eldridge and Reilly 2003). From 1986 through 1995, despite thousands of

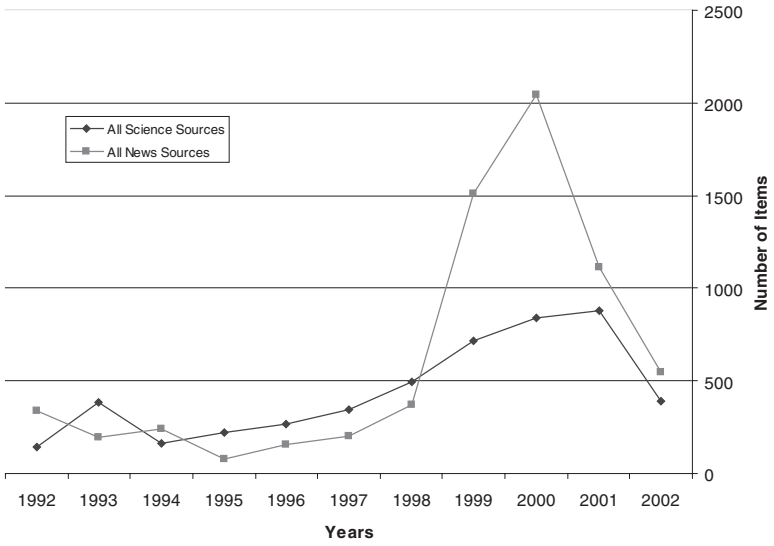

Figure 2: Publication Pattern of Science and Lay Literature Relating to GM Food, 1992-2002

reported cases of mad cow disease, there were few articles published in the UK press. Then, in 1996, when mad cow disease was shown to severely affect people who had ingested beef from infected cows, more than 35,000 articles were published in one year alone. Eldridge and Reilly (2003) attributed the lack of press attention to BSE during the ten-year period of increasing cattle infections to the fact that a long-term risk to people is seen as speculation and not news by journalists.

In 1996, biotechnology as a subject was only covered in one out of every twelve daily editions of the *New York Times*, but then coverage increased in an episodic manner when press releases were issued about various biotechnology "incidents," such as the cloning of the sheep named Dolly in 1997 (Nisbet and Lewenstein 2002). Our research showed that press releases announcing achievements in biotechnology food are one of the key factors in amplifying news stories and, consequently, creating a ripple effect of increased public awareness of a biotechnology issue.

As Retzinger points out, only 2 percent of Americans are engaged in agriculture, and fewer and fewer Americans have direct links to farming; few have the opportunity to learn about food production directly (2001, 1). Given the size of the U.S. population and the number of newspapers published

across the country, we found that there is relatively little published about GM food that is informative and substantially about the topic. As the following analysis and case study will confirm, the American consumer has a limited opportunity to learn about food biotechnology from the mass media until an incident results in the death of living organisms.

Content Focus of Stories about GM Food

Researchers examined the content of 20 percent of the 1,043 stories on GM food that appeared in 17 major U.S. newspapers (as contained in the Dialog PapersMJ full-text newspaper database) during 1999-2000, the years when the most GM news stories were published on the topic during a 10-year period. During the study, it became apparent that some of the articles retrieved did not have GM food as a central focus. The researchers wanted to examine the content of the stories to determine if they were substantially about GM food and, if so, which specific GM food topic(s) were covered in the stories. We examined a random sample totaling 218 articles to determine the core subject of each one. The headline and lead paragraph were analyzed by hand because key information about a story is generally presented in the headline and the first paragraphs of an article (Althaus, Edy, and Phalen 2001). The analysis scheme used was adapted from one used by researchers investigating television coverage of GM food (Robert Kubey and Mary Nucci, personal communication, 2003).

Results showed that stories about GM food are not always substantially "on topic." Articles appearing in the sample included stories about protests against globalization and biotechnology, both in Seattle at the World Trade Organization meeting in 2000 and in other places around the country; public opinion; trade; the environment; politics and public policy; health or medicine; the Monarch butterfly incident; the labeling of GM food; and the inclusion of GM corn (Starlink) in taco shells. The study also showed that twenty-seven of the items mentioned one of the food biotechnology terms, but these articles were basically "unrelated," that is, not essentially about GM food at all; none of the search terms appeared in the headline or lead paragraph of this set of twenty-seven stories. See Table 4 for a complete list and explanations of the topics found in the content focus analysis. Figure 3 shows the results of the analysis in graphic form.

The relatively high number of unrelated articles was confirmed by repeating the major U.S. newspaper search using an electronic searching technique that focuses the search terms exclusively in particular parts of the full text. In this case, instead of reading and examining the stories by hand, we did an electronic search asking for our terms only in the title, the lead paragraph, and

TABLE 4
Typology Used to Test Content Focus of a Random Sample of News Stories on Genetically Modified (GM) Food

Animal GM	The technology or technique for the cloning or genetic modification of animals.
Business/industry	Discussions of the economics, business concerns, or corporations engaged in the development and sale of GM food.
Butterfly	The effect of GM pollen on the Monarch caterpillar or butterfly.
Ecology/environment	Effect (positive or negative) of GM products on the environment.
Food	Consuming, cooking with, or selling food products other than Starlink and tacos.
Frankenfood	Emotion-laden rhetoric about GM food referencing hysteria, consumer fears, or technophobic attitudes.
General	Generally about GM food without fitting other content categories.
Labeling	Discussion of the need or call for labeling or nonlabeling of GM food products.
Plant GM	The technology or technique of the genetic modification of plants.
Politics	GM food mentioned in political discourse.
Protests	Coverage of protests related to GM food.
Public opinion	Discussion of surveys, polls, or other consumer research relating to GM food.
Regulation	Discussion of regulations or calls for regulations of genetically modified food.
Science/medicine	Biopharming, biomedicines, pharmaceuticals, and general information about genetics and genetic engineering.
Starlink and tacos	Starlink corn, not approved for human use, found in taco shells in the United States.
Trade	Trade issues related to the sale or transport of genetically modified food products outside of the United States.
Unrelated	GM food term is found incidentally but focus is not on GM food.

the indexing fields. One of these data elements in newspaper stories (title, lead paragraph, or index term field) usually includes a reference to the topic of the story. Searching for terms in the title, the lead paragraph, or the indexing reduced the number of items retrieved to 493 (from 1,043), a 53 percent reduction. This result indicates that not only unrelated articles but also those only obliquely related to genetically modified food were in all likelihood eliminated from the corpus of news media articles. In other words, during the

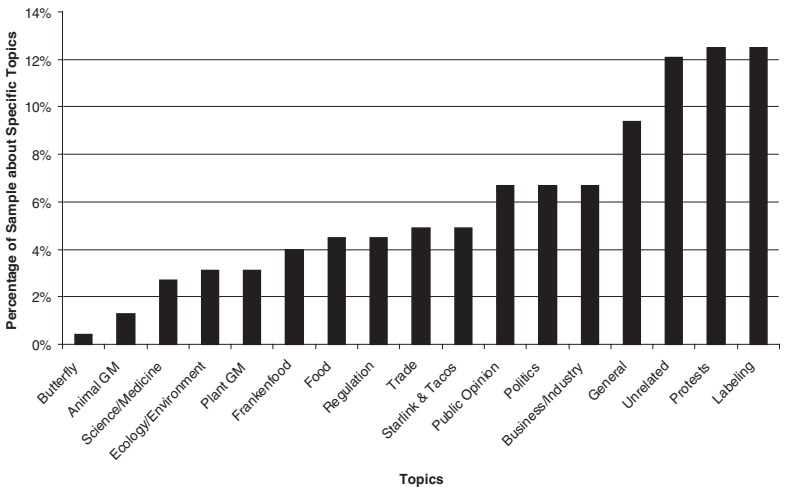

Figure 3: Content Focus of a Random Sample of Articles from Seventeen Major U.S. Newspapers, 1999-2000

2 years (1999-2000) when genetically modified food was covered by the American news media more than any other time during a 10-year span, only 493 news stories of all that mentioned GM food in 17 major papers were substantially about the topic.

The Influence of Science Incidents: The "Monarch" Event Case Study

The media serve as conduits of science information, with television and newspapers being the public's most used sources for the latest news on technology and science (National Science Foundation 2002). Thus, the media perform a valuable role in promoting scientific literacy and diffusing scientific information, as well as in shaping the public perceptions and understanding of science and scientific controversies (Nelkin 1995). As a science issue, GM food has become controversial for its potential impact on the human diet, existing patterns of food production, genetic diversity, and the environment. Because language can shape our understanding, it is useful to analyze what language the media have used to present GM food to the public. It has been shown that the language of a controversial science topic can be

highly politicizing, often confusing, and in other ways paradoxical (Reeves 2002). As shown in this study, multiple terms, including *agricultural biotechnology* and variants of genetically modified/altered/engineered food/crop, were all valid search terms (see Figure 1), indicating that the language in which this issue is presented is both nascent and undefined.

In analyzing the search results, it was also seen that the scale and pace of publishing for all terms changed suddenly in 1999, when total publications rose to 2,230. Nisbet and Lewenstein (2002) note in their analysis of the media discourse on biotechnology that specific events can have a profound impact on the publication pattern and emphasis of biotechnology-related news stories. Summarizing other research, they wrote, "Changing events can not only shift the balance of source influence, but they can also introduce new frames to a debate that may mobilize or allow access to interests previously not included in the media and policy agenda-building process" (Nisbet and Lewenstein 2002, 8). The actual reporting of the event can influence consumer opinion, but other informational aspects of the event can lead to social amplification as well. Citing examples like Three Mile Island and Love Canal, Roger Kasperson et al. (1988) detailed four mechanisms that might come into play as information flows from the source event. These are volume of the media coverage, disputation of the facts, dramatization, and the symbolic connotations embedded in the information.

In this study on GM foods, it became apparent that two events were critical to the increased level of media presentation. Researchers on the study noted in a preliminary analysis of search results that there were frequent references to two specific events: science research on the effect of GM corn pollen on the Monarch butterfly in 1999, and the recall of food products containing Starlink corn, a corn not approved for human use, in 2000. We theorized that these events were the impetus for the increase in publication of articles on GM food, even though all of the articles were not specifically on these two issues. The events served to spark interest in the subject of food biotechnology and resulted in an increased publication rate. This information was corroborated in a historical review by the Pew Initiative on Food and Biotechnology (2002) and in research by Hart (2002), Nisbet and Lewenstein (2002), and Winston (2002). Commonly referred to as the Monarch and Starlink incidents, these events affected the publication pattern of stories on GM food. The emphasis on Starlink in the media is understandable, because the American consumer was directly affected by Starlink in food products. But why was the event concerning the Monarch butterfly perceived as a crisis by the news media? What does it say about the flow of scientific knowledge to the public through the popular press? In the following case study, we use the

Monarch event as an exemplar of how an event that points to possible health-related dangers can spawn journalistic interest and publications and can increase public perception of risk.

The Monarch and GM Corn

In May 1999, *Nature* published the letter "Transgenic pollen harms monarch larvae" by John Losey, Linda Rayor, and Maureen Carter in the Scientific Correspondence section of the journal (Losey, Rayor, and Carter 1999). This section publishes peer-reviewed preliminary findings that introduce readers to "potentially important research before full publication of results" (Beringer 1999, 405). The letter presented findings indicating that 44 percent of Monarch butterfly larvae fed on milkweed leaves dusted with pollen from corn modified with a gene from *Bacillus thuringiensis* (Bt) die within four days of exposure. The letter also noted a significant effect on the butterflies' feeding behavior and, consequently, on how fast the larvae grew.

The modification of corn to produce Bt-corn allows the corn plant to resist corn borer larvae that usually burrow their way into the corn stalk, where they are protected from traditional pesticide treatment; therefore, Bt-corn offers farmers a valuable tool for pest management. At the time of the Losey letter, it was known that the foreign Bt gene expressed in the corn cells was poisonous to larvae of all species (Peacock et al. 1998), including the familiar Monarch butterfly, a nonpest species.

The authors of the letter commented in the last paragraph of the single-page correspondence that it is "imperative that we gather the data necessary to evaluate the risks associated with this new agrotechnology and to compare these risks with those posed by pesticides and other pest-control tactics" (Losey, Rayor, and Carter 1999, 214). In light of the fact that the findings presented in this communication were considered preliminary (twenty-five larvae were included in each of three groups: leaves dusted with pollen from Bt-corn, leaves dusted with pollen from non-Bt-corn, and leaves with no pollen), the authors' recommendations for continued research and risk assessment were sound science. The correspondence was never intended to be a report on fully researched scientific findings. Yet, on the same day that the communication was published (May 20, 1999), the story was covered by the *New York Times* (Yoon 1999), the *Wall Street Journal* (Kilman 1999), and many other newspapers, as well as being the subject of several AP Newswire stories. From a historical viewpoint, the letter set off a worldwide controversy over the effect of genetically engineered corn on the environment.

In their retrospective discussion of the issues raised by the correspondence, the Pew Initiative on Food and Biotechnology (2002, 3) commented

that this incident "generated intense national and international news coverage transforming the Monarch butterfly overnight into a dramatic symbol of what environmentalists and some scientists saw as the dangers of agricultural biotechnology." As the "crisis" of the Monarch controversy continued, the influence of specific sources for media stories changed (Berkowitz 1992); journalists turned to activist groups for information rather than to the traditionally favored organizations such as industry, government, or universities (Tuchman 1978). The imagery of the doomed Monarch butterfly promoted by these media underdogs put governmental regulatory organizations in a negative light and seemed to suggest that they were at fault for not fully regulating and controlling GM food.

Social amplification of informational flow mechanisms was at work here (Kasperson et al. 1988). The amount of newspaper coverage clearly escalated in 1999, as can be seen in Figure 1 after the flap created in the biotechnology community by the Losey, Rayor, and Carter letter. The facts about dangers to living organisms posed by Bt-corn were in dispute, and industry and activist groups took positions along a continuum of opinion about the meaning of Losey et al.'s research. The use of Monarch butterfly icons in protests and for fund-raising efforts signaled the dramatization of the event and also heightened the symbolism involved in the debate.

Role of the Press Release

To attract attention to their publications, many journals produce and transmit press releases to "encourage journalists working for the news media to bring the material they contain to wide audiences" (De Semir, Ribas, and Revuelta 1998, 294). Press releases afford journalists the opportunity to influence how the information is translated into news (Woloshin and Schwartz 2002). In a study of the British press, it was found that 81 percent of journal articles covered in the press were included in journal press releases (Entwistle 1995). Press releases are embargoed (available only to journalists) prior to their release date to allow journalists time to research and write their article for the media (Nelkin 1998). Press releases are designed to promote and publicize research, and rarely offer full and complete details, so this advance distribution gives the journalist time to assimilate and write up technical information (Nelkin 1998) as well as to contact experts other than those in the press release to verify facts and information. The Losey communication on Monarch butterflies was accompanied by five press releases: one each from the journal *Nature* (J. Webber, personal communication, January 9, 2003) and the Cornell University News Service (1999), where the research was performed; two from activist organizations (Greenpeace 1999; Union of

Concerned Scientists 1999); and one from Biotechnology Industry Organization (1999) in response to the activist press releases.

Data and Meaning

The public perception of science is influenced by how the press chooses to represent scientific data (Schwartz, Woloshin, and Baczek 2002). Mass media sometimes present data in exaggerated emotional terms couched in miracle cures, controversies, or technological disasters as a way to attract readers, while study limitations of scientific research are rarely mentioned by the media. It is fair to say that the media present the "broad brush" approach, painting data as clear-cut factual information and leaving the smaller details and subtleties of the research to more scholarly publications. In the case of the Losey communication, the data from the research were presented as solid fact, not as preliminary findings, resulting in a subsequent flurry of media articles portraying the Monarch butterfly as the sacrificial lamb of genetically modified crops.

Data presented in the media are often offered as "scientifically sound evidence rather than as preliminary findings with still uncertain validity" (Schwartz, Woloshin, and Baczek 2002, 2863). In spite of the fact that the authors of the *Nature* communication posited the results as having "profound implications" (Losey, Rayor, and Carter 1999, 214), indicating that the data were still in early stages, the coverage in the press was consistent with that used to present final results of a full-scale rigorous study. Because few readers search out original scientific journal sources (even if they are mentioned in the media), the public is restricted to the interpretation presented by the media.

Even though journalists attempt to control the media message, the meaning generated from an article in the popular press is affected by preexisting knowledge, including cultural biases, myths, or fears (Nelkin 1998). In a study on risk analysis, readers of science stories on risk felt less in control when the story emphasized the social or political aspects of science, and they felt more risk than readers of stories that emphasized the scientific or technical aspects (Hornig 1990). Technoscientific controversy analysis theory indicates that the public meaning of a controversy is determined by the narrative underlying it (Turner 2001). In other words, the way in which a story is told affects the reader's response. The narrative underlying the Losey correspondence pointed to the potential loss of the Monarch butterfly, connecting the issue in a public forum to problematic aspects of GM corn. All the complexities of the research were not available to lay readers, and the feeling of risk

may have been heightened because of the emotional and social responses elicited by images of butterflies ingesting "deadly" Bt-corn pollen.

Gamson and Modigliani (1989) note that the relative importance of media discourse depends on how readily available meaning-generation experiences are in people's everyday lives. The Monarch butterfly is well known, with its gaudy yellow, black, and orange stripes; its amazing migratory history; and its ubiquity throughout much of the United States. For those opposing GM corn, there could be no more potent symbol than this organism. The "signifier became more real than the signified" (Reeves 2002, 101), and the Monarch butterfly became the representative of science gone wrong. Of note is the fact that it was the larval form (the caterpillar) of the Monarch butterfly that was affected by the Bt-corn pollen, yet it was the adult form that became the symbol of opposition. Not all symbols, as noted by Gamson and Modigliani (1989), are equally potent. The caterpillar did not become the rallying symbol; the butterfly did.

The multiplicity of meanings generated from the simple communication in *Nature* reflects the heterogeneous nature of society. Gross (1994) noted that it is this heterogeneity that causes unknown and unpredictable results. In this case, the emotional appeal of Monarch butterflies dying from the Bt-corn pollen was broadly interpreted as a moral threat. Risk analysis has shown that the public and scientific communities have different interpretations of risk, which are often incompatible (Groth 2001). Scientists view risk quantitatively, while the public views risk qualitatively. By using statistical measures, risk analysts will explain that a certain behavior (traveling by plane, driving while drinking, smoking, etc.) all carry risk factors related to mortality rates or other outcomes. Even though the public may know the numbers and understand the risk percentages, moral acceptability by the public is a better predictor of support for an issue than risk or even usefulness (Ten Eyck, Thompson, and Priest 2001). The loss of Monarch butterflies could be construed as a quality-of-life concern in which the Monarch is seen as representing in microcosm the potential for significant environmental degradation and a threat to other life forms such as human beings. Just as seemingly fragile canaries were used to test the quality of air for coal miners before more sophisticated air-quality measures were devised, butterflies could be viewed as unintentional test subjects for GM food.

Activist groups were able to promote their concerns regarding the impact of genetically engineered food on the environment, and by implication on public health, thereby co-opting the symbolism of the Monarch butterfly to garner public interest and support for this issue. When an issue is in an early phase of the issue attention cycle (Downs 1972) as defined by Miller and

Riechert (2001), the news media as a whole become a dependent variable subject to influence by drama and conflict among the various stakeholders. In this evolving definition/conflict phase, conflict can "motivate stakeholders to increase their efforts to shape media" (Miller and Riechert 2001, 112). In response to activist press releases, Biotechnology Industry Organization (BIO), a major lobbyist group for the biotechnology industry, defended corporate interests by stating that company scientists took the environmental impact and health risks of their GM corn into consideration. By co-opting and adopting the message presented in the Losey letter, however, activists effectively cancelled out any defense of the scientific data, resulting in the Monarch butterfly becoming the "poster child" of the movement against GM food.

The public meaning of the Monarch/Bt-corn controversy was determined more by the narrative than by an analytic approach (Turner 2001, 476). It did not matter that the study was preliminary, a fact that the public might have understood more clearly if they had a greater understanding of the scientific process and scientific communication, but instead, the public generated meaning through their own chain of logic (Locke 2002). That chain of logic fostered the controversial aspect of the study and generated the response by the popular press—a press made up of members of the public who carry with them their own notions of meaning and value. As noted by Billig (1996, 102), even if the syllogism is noncontroversial, real arguments can always be lurking around the edges. The tactical use of expertise by the activist groups represents the multiplicity of possible stories in science rhetoric (Locke 2002), which in this case was exploited by opponents to GM food to support their concerns. As Peter Pringle points out, the Friends of the Earth used the following language in their campaign literature: "How safe is the food you eat? . . . If deadly toxins that kill butterflies are being introduced into our food supply, what effect are these toxins having on you and your family? . . . The scary answer is that no one really knows" (2003, 135). Given that there are a number of interpretations for any scientific study, and that it is only when that study has convinced a majority of scientists of its validity that it is accepted as fact, a single communication like this one in *Nature* can be interpreted and used by a variety of stakeholder groups in myriad ways.

In her classic article on the change in language from the science article to the public press, Jeanne Fahnestock (1998) noted that there is an accommodation that is made in the language as it moves from the scientific to the public realm. The relevance of science articles is "extratextual, not spelled out in the discourse but supplied by context, by the assumed inferences the audience will make" (Fahnestock 1998, 333). The "past" significance of discussing science results becomes the "now" or the "future" significance of the media.

Qualifications are removed, and results are thus associated with greater certainty. In the Monarch event, the preliminary nature of the study was the qualification that was eliminated in the popular press. These changes in language from science article to popular media are common, and the connotations can affect meaning. In the case of the Losey correspondence, the "harmful effects of transgenic pollen" in the letter became "engineered corn can kill Monarch butterflies" in the press release. It is the press release that attracts attention and draws the journalist to write the story. The deliberative then becomes the controversial as the journalist writes for a broad audience base, with its members having varying degrees of education, sophistication, and interests and who, in turn, interpret the meaning in the article through *their own* cultural background, imbuing the story with a meaning that may be far removed from the original intent of the scientist.

Conclusions

Public consciousness and interest in a science issue can be traced by retrieving items written about a subject through the use of large publication resources like Dialog and Lexis-Nexis; care must, however, be exercised in determining the most accurate and precise language because terms used to describe the same concept can differ among writers and indexers. It is easy to retrieve duplicate articles and therefore inflate numbers by including newswire stories, and it is easy to miss articles if enough sources and a comprehensive array of terms are not included. There is the ever-present danger of many false listings as well when imprecise search statements pull up irrelevant items. This study took great care in developing accurate key terms and in refining the search strategy and statements keyed into the retrieval systems. Multiple major newspapers were searched along with more than 400 magazine titles and thousands of science sources during a 10-year time span. The study showed that false results are easy to come by, and researchers should be cautious and conservative when estimating how much a story is covered in the popular press by relying on electronic information searching.

The information retrieval case of materials about GM food is an interesting one because of the number of terms and variety of language used in the scientific and lay discourse on the topic. The most commonly used terms for the topic are *genetically modified food*, closely followed by *genetically modified crops*, even though these are not the most "politically correct" terms. Our study showed that during a 10-year period, publishing in the area of GM food and crops steadily increased with certain events triggering large numbers of articles in 1999 (717 in science sources and 1,513 in the news and magazine

popular-press sources) and in 2000 (840 science items and 2,042 popular-press items). Published articles then tapered off in the next two years, most likely due to the fact that terrorism took center stage in the American public's mind. Scholarly publishing tends to be relatively static on this topic compared to the mass media.

Although the writing in scholarly scientific publications tends to be objectivist and reportorial, and the writing in the popular press more interpretive, sometimes scientific communication can be oversimplified, causing misunderstanding and putting into motion possible ripple effects of public concern. The Losey letter about Monarch butterflies being harmed by Bt-corn pollen shows how incomplete scientific knowledge and reporting can become problematic. Responding to the emotional appeal of the need to protect harmless, small creatures—Monarch butterflies—from risky food products, journalists can easily make the leap to writing about human beings in a similar context. In this case, activists gained power by co-opting the frames used to present the Monarch story. A relatively brief press release was reported and may have set an agenda of worry among the reading public. Indeed, it also brought fear of stigmatization to the biotechnology industry. In response to this small article, funded research was increased (Scriber 2001). Although it is beyond the scope of this article, the analysis of Web sites on GM food will no doubt find an additional influence of the Monarch event. A preliminary scan of Web sites showed both the Monarch graphic and stories about the Monarch being placed in prominent positions on antibiotechnology sites. And the ripples of influence from the event have continued for the press. As recently as January 2004, Kim Severson, writing in the *San Francisco Chronicle* about the discovery of mad cow disease in the United States, wrote the following:

> Every few years America gets a harsh wakeup call about the food supply. In the 1980s, it was the pesticide Alar contaminating apples. In the 1990s, it was genetically modified corn killing Monarch butterfly larvae and E. coli tainting fast-food hamburgers. (Severson 2004, paragraph 1)

This is only one portrayal of the incident. Overall, the study showed that the publishing pattern for the lay press does not exactly follow that of science communication when looking at the issue of GM food. In the case of the Losey article, because it was published in a widely respected journal and promoted by several press releases, a ripple effect was started. The ripples are still small, however. In the 2003 Rutgers study of consumers' perceptions of GM food, it was found that the U.S. consumer is still not sure about the safety of GM food. Thirty-one percent could not name a specific incident connected

to genetically modified food, and even those who could used vague phrases like "something about corn" (Hallman et al. 2003).

Except when a potentially risky event occurs, the news coverage of GM foods is minimal. The overall effect of the stories that are published in newspapers and magazines has been to amplify concern and to set the stage for more analysis of GM foods by scientists, science journalists, advocacy groups, and the reading public. Especially in the case of corn, a food that has a noble history in the Americas, a food that meant life to the ancient Mexican and Pueblo Indians (Hart 2002), the debate over GM food is a worthy one, and it is a story that scientists and journalists are certain to follow with interest and investigation in the years to come. The American consumer, perhaps the biggest stakeholder in the U.S. controversy and who is now somewhat in the dark about the issue, will be paying attention as well.

Notes

1. At one point, the Food and Drug Administration (FDA), one of the U.S. federal oversight agencies for genetically modified foods, urged journalists to avoid the term *genetically modified food* because of the frightening implications of genetic changes to any organism, especially one that humans might ingest. In 2001, John Levitt, director of the FDA's Center for Food Safety and Applied Nutrition, said that companies should not label their products with terms such as *genetically modified (GM)* or *genetically modified organism (GMO)*; in fact, even the word *modified* was not recommended. As an alternative, Levitt said that manufacturers of food products should use terms such as *genetically engineered* (Formanek 2001). Journalists certainly did not follow the dictum to use *genetically engineered* to describe genetically modified food. They continued to use GMO and *genetically modified*, as the numbers indicate. See Figure 1.

2. The ongoing research project is also analyzing published material on Web sites and transcripts of television news special shows; this article, however, reports exclusively on articles published in journals, newspapers, and magazines from 1992 to 2002.

3. Bt-corn varieties have been genetically modified to express the toxin produced naturally by the bacterium *Bacillus thuringiensis*. Different varieties are manufactured by different companies and have various trademarked names.

4. The numbers represented here include publications in scholarly science journals as well as articles in the popular press.

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