Public Health and Agricultural Biotechnology: A Review of the Legal, Ethical, and Scientific Controversies Presented by Genetically Altered Foods

by

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PUBLIC HEALTH AND AGRICULTURAL BIOTECHNOLOGY:

A REVIEW OF THE LEGAL, ETHICAL, AND SCIENTIFIC

CONTROVERSIES PRESENTED BY GENETICALLY ALTERED FOODS

By
Mitchell Berger

A report submitted to the Faculty of the Department of Environmental and Occupational Health of the Rollins School of Public Health of Emory University in partial fulfillment of the degree of Master of Public Health.

Emory University

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PUBLIC HEALTH AND AGRICULTURAL BIOTECHNOLOGY

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ABSTRACT

Genetically modified foods present numerous ethical, environmental, health and legal challenges. This report synthesizes information from many websites, scientific journals, newspapers and books that discuss the controversy surrounding genetically modified foods. The author has attempted to show that although the future applications of agrobiotechnology appear promising, the ways in which it is currently being used and regulated should be evaluated with a healthy degree of skepticism.

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I. Introduction

> "Never before has the course of basic scientific research been so thoroughly and single-mindedly driven by commercial considerations. Each new product contains profound implications for the integrity of natural ecosystems, the humane rearing of domestic animals, the safety and quality of the world's food supply, the virulence of common plants and insect pests, the survival of small farms, the nature of medical care, and the ethics of genetic experimentation itself. But with hundreds of agricultural products and scores of new drugs being developed and tested in the US alone, it is difficult to imagine how activists or government regulators (if they were so inclined) could respond individually to every new product and every new discovery"-Brian Tokar 1995 Z magazine

With or without their knowledge, most Americans are probably already eating biotech foods. Did you celebrate Thanksgiving this year? If so, your stuffing and gravy may have contained genetically modified soybean oil. Grandma's classic whipped cream may have contained milk from cows raised on bovine growth hormone. Cranberry sauce may contain corn syrup from corn modified to contain genes from *Bacillus thuringensis (*BT), a powerful microbial insecticide, or other genes that allow the plant to resist powerful chemical herbicides. Potatoes may be also have been modified to express BT genes. The canola oil for the sautéed onions and salad dressings may have been engineered for herbicide resistance. So too the cottonseed oil in the chips. Even the turkey may have been raised on genetically modified foods! (Martin 1998)

Even for those who are aware that many food crops have been genetically modified, the wide variety of foods that may contain genetically modified components may be surprising. Avoiding tofu, for instance, probably won't be enough to ensure that one is not consuming GM soybeans. As it turns out, up to 60% of processed foods and 80% of vegetable oils contain soybeans or soybean components (e.g., lecithin oil). [1]Mike Wilkinson (1998) recently noted in *Nature* that "nearly all foods containing soya are also likely to contain some proteins originating from genetically modified beans". Baby foods,

[1] Some commonly used ingredients made from soybean oil that may contain GE include: lecithin, oil, flour and hydrolyzed or textured vegetable protein. Ingredients that could be made from GE corn include:

chocolate, bread, pasta, cookies, and ice cream are examples (Shiva June 27 1998; Krebs Mar. 9, 1999; Allen 1999b; Webster 1999), McDonald's fries may have been made from genetically modified potatoes (Montague 1999). Coca-Cola may contain corn syrup or aspartame made from GM corn.[2] At least 50 plant foods have been genetically modified and hundreds more are in development; of the 860 genetically altered plants field tested as of 1993, 90% were food crops according to the United Nations Environmental Program (Allen 1999b ; Glick and Pasternak, 1998; Mgendi 1999; Betts 1999). Nine GE food crops are currently grown in the US for commercial purposes (Betts 1999). [3] But that tells only part of the story because many other foods may contain genetically modified ingredients. Indeed, over 30,000 baked or processed items now on the market in the US may contain GM ingredients (Montague 1999; Walsh 1994; Webster 1999). This represents up to 60% of processed foods (Health risks, Lancet, 1999). Some popular foods that may include genetically modified ingredients are: Frito-Lay doritos and corn chips (corn), El Paso taco shells (corn), Kellogg's (corn flakes), General Mills (Total and corn flake cereals), Nestle chocolate (soy), Quaker granola bars, Aunt Jemima pancake mix, Kraft salad dressing (canola); Fleischmann margarine (soy) and Land O' Lakes butter (BGH); Enfamil, Alsoy and Similac infant formulas (soy); Green Giant and McDonald's veggie burgers (Soy); Ultra Slim Fast and Ovaltine's weight loss products(Montague 1999; Suderman 2000). And many more such foods are planned. In 1998 alone, several new types of GE soybeans, sugar beats, garlic, corn, cotton, tomatoes, flax, rapeseed, radicchios rasso, squash and potatoes were introduced

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maltodextrin, corn syrups and starches (Coghlan March 27, 1999).

[2] I use the terms "genetically modified"(GM) and "genetically engineered"(GE) interchangeably to refer to foods that have been produced using modern biotechnology methods such as transformation with Agrobacterium, see below.

[3] These nine crops, with number of GMO varieties and source of genes for modification in parenthesis, include: canola (4; plants, bacteria); corn (13; bacteria, corn, virus), cotton (5;bacteria, tobacco, virus), papaya (1; bacteria, virus); potatoes (1; bacteria); chicory (1; bacteria); squash (2; virus); soybeans (3; plants, bacteria, virus); tomatoes (5; tomato, bacteria, virus). From Betts 1999.

or in advanced testing. (See Genetically modified food ingredients to watch 1999; McKee 1998;Cookson 1998; Food-Test/Report, Consumers Union 1999).[4]

Haven't heard about this? That's not surprising. The US Food & Drug Administration, which governs food labeling, determined in 1992 that genetically modified (GM) or engineered (GE) foods were "substantially equivalent" to conventional foods. As a result, producers need not notify consumers that their products are genetically modified or include GE ingredients.

Are consumers right to be concerned, or is the controversy over GE food yet another example of paranoia and Luddism? By way of perspective it is interesting to consider the controversy surrounding atomic energy about thirty years ago. In 1956, a classic Disney film introduced viewers to "Our Friend the Atom". The film drastically overestimated the benefits and understated the risks of atomic energy, showing, for instance, atomic powered aircraft (Bikowicz)! On the other hand, some new technologies such as lightning rods and automobiles were initially rejected as unethical or even evil, yet today are generally accepted[5]. Will today's biotechnology, optimistically characterized by Monsanto as holding "Solutions for tomorrow's world", prove to be a resource to humanity or a threat to both human health and the environment (Anderson 1999; www.monsanto.com)? This thesis discusses the current scientific and ecological concerns about genetic engineering and argues that foods should be labeled so that consumers may better evaluate the risks and benefits of genetically altered foods. Increased knowledge about the legal, medical and ecological issues concerning GE foods can help enhance citizen involvement and generate potential solutions.

[4] Consumers Union found its test of cereals to be "inconclusive", but Suderman, citing Consumer Union and Genetic-ID data, does provide information on cereals. As of March 2000, several companies, including Frito-Lay, a division of PepsiCo, are reevaluating their position on GE. Of course, at the same time some corporations cease using GM ingredients, others may begin using them.

[5] However, James Kunstler (1993) and Edward Tanner (1996) point out some of the adverse health and environmental effects of cars.

II. Background

A. Basic techniques of plant biotechnology

Biotechnology can most simply be defined as the science of genes— how to locate genes, discover their function, and use them to produce products beneficial to humanity. The FDA defines biotechnology as “techniques that allow scientists to modify DNA, the genetic material of living things” (FDA 1994). Human cells contain hereditary information encoded in the form of deoxyribonucleic acid (DNA). DNA consists of a sugar (deoxyribose), a nitrogenous base (adenine, guanine, cytosine, thiamine) and a phosphate group. The nitrogenous bases are complementary-adenine binds to thiamine and cytosine to guanine. Hydrogen and disulfide bonds result in DNA taking on the familiar double-helix conformation. The nucleus of each human cell contains DNA in the form of chromosomes. Chromosomes contain thousands of base pairs of DNA. Each stretch of deoxyribonucleic acid (DNA) that encodes a particular protein or function is called a gene (Pepa 1998). Various enzymes transcribe DNA into messenger RNA. Following transcription, the mRNA is “translated” into one of 20 different amino acids. But genes are not purely structural or informational units in the sense that a gene in one species will have exactly the same effect in another even though all organisms share the same amino acids. Consider this analogy. English and French may share the same letters but the way they are used to communicate differs greatly. If one takes words from English and randomly inserts them into a French sentence, then although the letters, and even some words, may be the same, one is bound to distort the overall meaning of the phrase. The same may be true in genetic engineering. As biology professor Johannes Wirz of Open University in Britain observes genes are functional units. For example, human retinoblastoma gene can be introduced into mice. Mice will then have the genotype (same DNA) for the illness but experiments show that the phenotype, the

alteration caused by the presence of the gene, in this case retinoblastoma, does not occur in mice. In addition to its basic structure, in every organism the gene has a certain function and “context” that must be considered. If a gene is to be moved from species X to species Y, then one must consider not only the structure of that gene but also how it will function and interact with other genes in its new genetic environment (Wirz 1995). “ ‘No gene ever functions in isolation,’ “ according to Open University (UK) geneticist Mae Won-Ho (Tokar 1995; Ho 1998; Lewontin 1991).

According to the FDA-EPA-USDA Coordinated Framework for the Regulation of Biotechnology, 51 Fed Reg. 23302 (1986), genetic engineering is “the use of in vitro techniques for the deliberate manipulation of genes within or between species for the purpose of gene analysis and product improvement “ (See also Steen 1996). Transgenic technology “involves the creation of plants and animals that are genetically engineered either to contain foreign genes or exclude existing ones” (Pepa 1998). A transgenic plant or animal can defined as “one in which a gene has been physically inserted into the nucleus of an embryonic, stem or germ cell such that the gene is present in the somatic cells of the organism” (Council on Scientific Affairs, AMA 1991). Transgenic animals function as living test tubes ” that can help produce beneficial drugs and proteins or observe the effects of the presence and absence of certain genes”. Biotechnology, by comparison, refers to the slightly broader use of “technolog(ies) that employ biological or living systems …for the production of industrial goods and services” (Harrlander 1989). Using yeast to make beer or bees to make honey or bacteria to make yogurt are examples of biotechnology. A genetically modified food can be thought of as a “cro[p] modified to be resistant to insects and weedkillers and to help food processing” (British survey 1998).

Until the development of recombinant DNA or genetic engineering, scientists had to work with thousands of genes at once in trying to see how genes work. One author

points out that "[t]his situation is analogous to a Frenchman hovering a kilometer above Washington, D.C. in an attempt to learn the English language—the roar of a million voices would make this an impossible task"(Pepa 1998). DNA engineering uses plasmid vectors to isolate a single gene and "amplify its voice in an effort to learn the particular genetic language". Plasmids are small circular DNA molecules that are found in bacteria along with the bacteria's own genome. Plasmids can self-replicate and be transferred between bacteria through conjugation, one way in which bacteria replicate. If a gene of interest is inserted into a plasmid, rapid bacterial growth and division will replicate a large amount of plasmid DNA within a short time. DNA splicing enzymes can be used to cut and splice the gene of interest into the plasmid. Basically, these enzymes, known as restriction endonucleases, cut out a section of the plasmid DNA and leave blunt or sticky ends where the DNA of interest can be inserted. Currently, this DNA is taken from other plants or animals, but eventually synthetic DNA may be developed (Thompson 1997). Once the DNA has been placed in the genome of the plasmid, other enzymes then seal the DNA in place. Each restriction endonuclease cuts each piece of DNA at the same place every time like a pair of scissors. Scores of these enzymes have been isolated and catalogued by scientists and are sold by corporations such as New England Biolabs (http://www.uk.neb.com/neb/). DNA is broken into large fragments and then forced into the bacteria. Not all bacteria will have all the necessary fragments of DNA. However, the mixture can be grown, making it more likely that eventually single bacteria will have all the fragments of DNA that comprise the gene of interest. Colonies can then be grown from these modified bacteria (Burke 1998).

Currently, there are three key methods for plant bioengineering. One method relies on a species of bacteria known as *Agrobacterium tumefaciens*, which infects plants. The bacteria causes large "galls" or "plant tumors" that are visible to the naked eye as large bumps on tree branches. This particular method first became widely used in

1984 (Paszkowski 1989). Agrobacterium is infected by a plasmid (the Ti plasmid) that can enter cells in host plants and integrate its DNA into the plant genome. Normally, this occurs as a natural process in dicots (such as tomato, potato, carrots and tobacco) but not monocots such as maize, rice and wheat. However, new technology has allowed scientists to use *Agrobacterium* to genetically engineer monocots as well as dicots to express traits desired by humans (Bennett 1993;Stark; Kappeli and Auberson 1998; Glick and Pasternak, 1998; Kado 1998; Shimamoto 1995). Plasmids expressing the desired DNA for a trait, say herbicide resistance, are placed in *Agrobacterium*. Plants are infected with the bacteria and the DNA from the plasmid enters plant cells, leading to the desired transformation. In effect, “the bacterium then acts as a microengineer doing all the work"(Montague Oct. 1998;Bennett 1993). But using the bacterium in such a way has its downside: scientists can infect the plant with the desired DNA, but they cannot control where (or even if) that DNA successfully integrates into the genome of host plant cells. As a result, the inserted DNA may change key sequences within the plant genome, leading to unpredicted effects; altered nutritional composition, for instance (Montague Oct. 1998; Council on Scientific Affairs, AMA 1991).

Another method of modifying plants--the biolistic or “gene gun” method—uses helium, compressed air or gunpowder to propel tiny (0.4-1.2 μm) gold or tungsten pellets coated with DNA into plant cell cultures (Council on Scientific Affairs, AMA 1991,Christou et al.; Bennett 1993;Stark). The fragments penetrate plant cell walls and the DNA enters nucleus and host cell chromosomes without damaging crucial cell organelles. This method is useful for cereal crops that may be immune to infection by *Agrobacterium*.

Other methods to transform plants use techniques such as microinjection or electroporation to remove the plant cell wall in order to make access to the nucleus easier for foreign DNA or try to regenerate protoplasts transformed by direct gene

transfer or liposome fusion into viable plants (Palca 1999 BBC 6 April 1999;Klein et al., 1984;Biotechnology 1997;Bennett 1993;Stark; MacCormick et al. 1997; Glick and Pasternak, 1998). A protoplast is the living material of a cell (e.g., no cell wall or membrane). Protoplast transformation can be accomplished by electroporation or polyethylene glycol. Unfortunately, protoplasts may not have the same patterns of gene expression as their parent cells. Also, regeneration of protoplasts into whole plants is difficult (Klein et al., 1984). Furthermore, in some cases, as with microinjection, the method has limited utility because only one cell can be transformed at a time (Glick and Pasternak, 1998). Despite these difficulties, embryonic cultures of cereal crops such as rice have been established using protoplast transformation techniques (Klein et al., 1984).

Generally, the plant will be transformed with the gene of interest (e.g. herbicide-resistance) along with a marker or reporter gene to help scientists identify those plants that have been successfully transformed. Genes coding for resistance to antibiotics such as ampicillin, kanamycin or neomycin are often used as markers. Reporter genes include genes that are colorimetric, radiometric or luminometric—that is, scientists can identify the transformed plants by their color or the appearance of the plants under certain wavelengths of light (Bennett 1993). In both the gene gun and *Agrobacterium* methods, the infected cells are regenerated into whole plants. These plants are cloned, and then mass-produced. Engineering of disease resistance relies on the “set a thief to catch a thief approach”. Plant viruses have nucleic acids surrounded by a protein coat. To break free of the cell, the nucleic acids must uncoat and act as a template for the synthesis of more viral nucleic acid. When a sufficient amount of new DNA/RNA has formed, the virus signals production of massive amounts of coat protein to encapsulate the newly formed nucleic acids. Thus, new virus particles are formed. Incorporating the gene for a specific virus coat protein into DNA and integrating it into the host plant can

render the plant immune to that virus. When the virus is confronted by preexisting coat proteins, it immediately attaches to the coat protein DNA previously introduced into the plant, thereby preventing it from synthesizing viral progeny (Bennett 1993; Glick and Pasternak 1998). Gene modifications that might discourage infected plant cells from self-destructing (apoptosis) or trigger more localized hypersensitive reactions that can limit damage while still conferring systemic immunity on the plant are also being explored (Swords 1999).

From the outset, it should be clear that defining GM foods requires making several "interpretative judgments that may be controversial". A broad definition would include plants and animals created with recombinant DNA as well as food products made by GE microorganisms such as bacteria modified to produce rennet, a key enzyme in cheese making (Thompson 1997; Harlander 1989; Dixon March 11,1999). Also, "negative" and "positive" modifications must be distinguished. While "negative" modifications might seek to prevent allergies or decrease toxicity, "positive" modifications would attempt to improve nutrition or confer disease resistance. These modifications may have different ethical and scientific ramifications (Hughes 1996).

B. The players in plant biotechnology

1.Corporations

In the next century, the ideal product for the life sciences industry will be a " 'new breakfast cereal that cures cancer' ". (Nelson 1999) Genetic engineering may save lives and help the environment. But it could also prove to have serious adverse consequences. The future ethical and scientific impact of GE remains open to question. However, biotechnology is already proving profitable for the key players in what the Rural Advancement Foundation International [RAFI] calls the "life industry" (www.rafi.ca).

According to the Organization for Economic Cooperation and Development (OECD), biotechnology is one of the world's fastest growing industries (Gary 1998; 39). In 1997, GM foods raised about $4 billion in sales (Sze and Arnum 1998). By the year 2000, biotech may be a $75 billion/year industry (van der Gaag 1994). About ¾ of this revenue will come from agricultural biotechnology. In England alone, over 460 companies employ almost 40,000 people with 20% employment growth each year (Sime 1999). In the US, there are over 1200 biotech companies employing about 153,000 people (Some facts about biotechnology 1999).

Even without GE, the food biotechnology industry has been taking on monopolistic aspects, as consolidation occurs within and between companies in the agrochemical, food, drug, and seed industries. "The fusion of food and pharmaceuticals and the transdisciplinary aspects of biotechnology as a whole make such a move perhaps the most logical strategy for the huge life sciences conglomerates," explains RAFI (1997). For example, by 1996, the world's top 10 agrochemical companies accounted for 82% of sales in that market (Bragdon and Davies, 1996;Chamberlain 1997). Similarly, the top 10 seed companies have captured 40% of the commercial seed market and the top 10 pharmaceutical companies account for 36% global drug sales (Bragdon and Downes 1998). Given that many economists believe that domination of more than 40% of an industry is monopolistic, the power of these corporations becomes clear (De Vore 1999). Large companies dominate on both the supply side (chemicals and seeds) and on the market side (processing, transport)(De Vore 1999). Large companies such as Monsanto and DuPont have sold their oil or chemical divisions to other companies in order to focus on biotechnology (RAFI March/April 1999). As Jeremy Rifkin observes, " 'That signals the passing of one era and the beginning of another" (Interview). This enhanced focus has had results: in 1990, there were about 30 major plant food-engineering companies; today there are just seven (Massaging mother nature 1998; RAFI Nov/Dec 1997;Stark).

Author Neil Munro asserts that the structure of the biotech industry is “not much different from the baseball industry. Several large pharmaceutical firms select promising products developed by roughly 1500 smaller, risk-taking research firms competing for a slot in the major leagues” (Munro 1999; Bhattarai 1996). To use Munro’s analogy, major-league players include Novartis, Hoffman-LaRoche, American Home Products and DuPont, Mycogen, Zeneca, AgrEvo (Hoechst/Schering AG joint venture), Rhone Poulenc Rorer and Cargill (Munro; Sze and Arnum 1998). Powerful agents also represent these large corporations: the American Crop Protection Association, the Pharmaceutical Manufacturers Association and the Biotechnology Industry Organization are just a few of the major industry groups. Since each new product takes about 10 years and $500,000,000 to develop only rarely can a smaller company make it to the “big leagues” without help in the form of strategic alliances or mergers with larger companies. Once the smaller companies on the “farm [pharm?] teams” have developed a promising product, the company will often merge with a larger partner, form a strategic alliance or allows a larger company to buy a controlling stake in the business. In short, “the road to a fully integrated biopharmaceutical company is a long, risky and expensive one” (Lahteenmaki et al. 1999).

Like big league athletes, large companies also swap and trade amongst themselves through mergers and acquisitions. Monsanto is by far the largest player in the industry. The company, claims one author, is “positioning itself to become its [the biotech industry’s] Microsoft, supplying the proprietary ‘operating systems’-the metaphor is theirs-to run this new generation of plants” (Pollan 1998). Novartis, another giant corporation, was formed in 1995 by the merger of Ciba-Geigy and Sandoz (Biotech makes wheat, riboflavin; Food Ingredient News Feb 1, 1997; RAFI Nov/Dec 1997). Novartis is the largest agrochemical company, the second largest seed company, the third largest human drug company and the ninth largest veterinary medicine corporation (RAFI

Nov/Dec 1997). Aventis, which will soon be the world's largest pharmaceutical company, was formed in 1998 by the merger of Rhone-Poulenc Rorer and Hoechst Marion Roussel (http://www.rhone-poulenc.com/). In the food industry, Cargill is buying the grain assets of Continental Grain Co and, pending Department of Justice approval, will soon control 45% of the grain trade, 40% of the maize trade and 33% of the soybean trade (RAFI March/April 1999). These are just a few illustrations of consolidation in the food, drug and agrochemical industries, but they prove the point that an ever-fewer number of players are dominating a growing "field" of industry[6]. To be sure, these companies are also fierce rivals—Monsanto and Zeneca, for example, are engaged in a fierce intellectual property dispute about licensing of GE soybeans (Kleiner 1998). But the fact remains that these companies share a similar interest in extending the commercialization, ownership and sale of genetically modified foods and other products. Likewise, the companies are likely to share similar views about government regulation and many citizen concerns.

DNAP Holding corporation is typical of many "minor players" in the industry. The company has developed modified tomatoes, carrots and peppers and is researching GE strawberries, melons and bananas. DNAP Holding Corporation was founded in 1981 by former Campbell Soup scientists and merged with Advanced Genetics Science. In 1996, the corporation merged again with Empresas La Moderna, a large Mexican conglomerate. In 1997, the corporation formed an alliance with Monsanto (Sze and Arnum 1998; http://206.184.157.225/News/Companies/ USA/DNAP.htm). [Empress also owns Seminis Seeds which controls 40% of the US vegetable and fruit seed market Collaboration… Food & Drink Weekly, July 6, 1998]. Also, in 1997 the company acquired the intellectual property rights of another small biotechnology corporation. In 1999, the company changed its name to Bionova Holding company; Bionova was a subsidiary of Empresas La Moderna, the

[6] According to the Biotechnology Industry Organization, there were 73 mergers of biotech companies in 1997 alone (Biotechnology Public Market, 1998).

conglomerate with which DNAP merged (Sze and Arnum 1998). In 1999, Novartis and DNAP signed a licensing and financing agreement.

As the key players in the seed, pharmaceutical and agricultural markets grow bigger and more intertwined, the boundaries between industries in these markets become less clear. The combination of intellectual property rights and firm consolidation "may have synergistic effects on market power that are problematic for consumers, farmers, competitors and innovators" (Bragdon and Downes 1998). Besides selling genetically modified products, for instance, these corporations also fund and finance important research. Novartis recently announced plans for a $600,000,000 Agricultural Discovery Center to help find "new targets" for transformation to help postpone weed or insect resistance to modified varieties (Novartis announces 1998). In addition, Novartis recently concluded an agreement with Berkeley that will give the company right of first refusal to about 40% of new discoveries made in that university's Department of Plant and Microbial biology labs in return for a $25,000,000 grant to the university for non-targeted research (RAFI March/April 1999; Sanders 1999). Large corporations are also funding efforts by smaller companies to identify, analyze and patent plant genes (Riechmann et al., 1999; Marshall 1999).

The growing power of corporations in the life industry is not only of concern to investors, but also to farmers, scientists and consumers(RAFI March/April 1999; Macer 1990). RAFI [Rural Advancement Foundation International] cautions that "neglect of the public good is inevitable when the research agenda is determined by the private sector in pursuit of corporate profits" (RAFI March/April 1999). As multinational corporations become larger and less dependent on the approval of specific governments, RAFI's warning may prove even more valid. In addition, there is the danger of externalities--that the public may be forced to deal with the economic and social downsides of GE, while private organizations reap the benefits of the genetic revolution (Heaf 1998). While RAFI may be

exaggerating, emerging trends in the industry already justify some of the organization's concerns.

2. Governments

Governments and philanthropic foundations are deeply involved in both research and funding aspects of genetic engineering. About 44 government-sponsored organizations have been formed to promote biotechnology in the third world (Komen 1997). Many promote the idea of a second "greenhouse revolution" (Tokar 1995). Some, such as the Consultative Group on International Agricultural Research (CGIAR), are operated under the auspices of the United Nations, Food and Agricultural Organization or the World Health Organization. CGIAR consists of 16 key agricultural research centers including the International Rice Research Institute in the Philippines and the International Food Policy Research Institute in Washington, D.C. (http://www.cgiar.org/centers.htm; Bragdon and Downes 1998; Pearce 1998). The International Potato Center in Lima, Peru is also supported by CGIAR (http://www2.bonet.co.id/cip/ About-CIP.html). Other UN agencies such as the UN Development Program also help fund research on the development and applications of modified foods (Komen 1997). Both the World Health Organization and Food and Agricultural Organization have statements and policies pertaining to genetically modified foods. The United Nations Educational, Scientific and Cultural organization (UNESCO) supports training centers for scientists from underdeveloped nations (Munro 1999; Brink et al., 1999). Other organizations such as the UN Industrial Development Organization advocate " 'capacity building' " in the third world, so third world researchers can contribute to biotechnology. But where proponents hope for a growing number of well-trained third world scientists working in first-rate facilities, opponents worry about health ministries being "coopted" by biotechnology interests (Tokar 1995).

Individual governments such as the United States also help promote biotechnology. For instance the United States Agency for International Development (USAID) has funded research into the micropropagation of bananas, cucurbit and tomato transformed to resist important viruses and maize resistant to stem borers (Komen 1997; www.info.usaid.gov). Switzerland helps fund and operate the Indo-Swiss Collaboration on biotechnology. France and the Netherlands also fund biotechnology research organizations (Komen 1997). Governments may also work with corporations. For instance, Rhone-Poulenc Agro [France] and Singapore's Institute of Molecular Agrobiology are working to isolate virus resistance genes in rice (GMF market intelligence April 1999).

Involvement by international agencies, of course, is not above criticism. Some believe that projects by USAID and other agencies "serve as 'window dressing'…that obscures an uglier reality" (Lappe et al.1998). For instance, one author asserts that the main goal of USAID projects in Central American helped make the US presence more "palatable" and distracted from US intervention in Nicaragua and other nations (Lappe et al. 1998). Wealthy individuals in third world nations, US companies and university consultants may sometimes benefit more than the poorest farmers for whom the aid is presumably intended (Lappe et al. 1998). As discussed below, some fear that the current plight of those in third world may actually be made worse by the introduction of biotech foods.

3.Non-governmental Organizations (NGO's)

Private foundations such as the Rockefeller Foundation have been instrumental in promoting biotechnology development and often work with governments, especially in the third world (Nelson 1999; www.rockfound.org). Data from non-governmental agencies such as the Rural Advancement Foundation International, Greenpeace,