# *Dangerous Liaison–Deadly Gamble*

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## THE RULE OF BAD SCIENCE AND BIG BUSINESS

Genetic engineering biotechnology is hailed as the solution to all the problems facing humanity. It promises food for the starving billions in the Third World, greener agriculture, miracle cures and vaccines for cancer and other diseases, genetic diagnosis, gene therapy, genetic enhancements and even cloning of human beings. It threatens to change every aspect of our lives, not the least of which, our value system as human beings. Why is there so little debate?

In particular, why is almost no one questioning the science, which is taken to be unadulterated good not just by spokespersons for the industry, but also by our government representatives, by scientists, and the mainstream media? It is the latest offering in a reductionist tradition that has already brought us radioactive and toxic wastes, greenhouse gases, holes in the ozone layer, agrochemicals, environmental degradation, and other legacies of the Green Revolution. Can it really solve problems that reductionist science has created in the first place? Or are we facing dangers of a different order than anything that reductionist science has given us so far? I shall confine discussions to agriculture, although many of the main arguments are relevant to human genetics where major moral issues are raised in genetic discrimination, eugenics, and human cloning. A more comprehensive treatment can be found in my book: *Genetic Engineering: Dream or Nightmare? The Brave New World of Bad Science and Big Business* (Ho, 1998).

The reality, in my view, is that bad science and big business, both out of control, have formed a dangerous liaison that is gambling with our food security, biodiversity, and health, and at the same time tearing at the fabric of civilized society. The liaison is reinforced by a shared mindset that claims to

be objective and neutral, but in reality, starts from some pretty simplistic and immoral assumptions. They see the world in bits and pieces, as selfish genes and selfish individuals instead of organisms, societies, and ecosystems. All of nature, including human beings and their genes, are objects to be manipulated and exploited for gain. Life and business are both in a competitive Darwinian struggle for the survival of the fittest.

The corporations are getting bigger and more competitive all the time. Just six agrochemical giants are poised to take control of world food production and distribution: Monsanto, Novartis, AgrEvo, DuPont, Zeneca and Dow (Vidal and Milner, 1997). In international financial organizations such as the World Trade Organization (WTO) and the Multilateral Agreement on Investment (MAI), legislation is being rewritten to remove all real or perceived barriers to trade and investment to enable corporations to better exploit the poor and the weak, to maximally internalize profit, and to externalize risks and costs with impunity (unpublished manuscript). At the same time, restrictive "trade related intellectual property rights" are to be protected, the most immoral of which are the patents on life that include seed varieties and knowledge stolen from Third World countries, as well as genes and cell lines taken from indigenous peoples under false pretext (Baumann, et al., 1996).

Patents on transgenic crops and other organisms will turn farmers everywhere into contracted laborers, and drastically reduce agricultural biodiversity as farmers will no longer be free to grow non-certified varieties. Farming will concentrate into fewer hands, displacing millions of small farmers or throwing them out of work by destroying export markets. Patents on human genes and cell lines will compromise healthcare for ordinary people who cannot afford to pay royalties or license fees. Basic scientific and medical research will also suffer. Most of all, these patents effectively grant monopolistic ownership of living organisms, including human beings and their genes, to powerful corporations that cannot be held accountable. Unfortunately, intense lobbying by the biotechnology corporations has persuaded the European Parliament to vote in favor of a directive that will make these patents legal. Patents that violate basic human rights are being legitimized by the dominant reductionist science that purports to set standards of propriety and probity.

This same science is also setting standards of what is safe, as we are repeatedly told by expert scientific committees at the United Nations, the European Union, and many national governments that have approved nearly all the genetically engineered products to date. The key concept is the "principle of substantial equivalence" on which all risk assessment is to be based. This principle is elaborated in a report issued jointly in 1996 by the Food and Agricultural Organization (FAO) and the World Health Organization (WHO), whose Codex Alimentarius sets world safety standards. It would be deemed illegal for countries to ban imports of any genetically engineered products so long as the Codex considers them safe. The principle is validated

by the science, which pronounces that there is no essential difference between transgenic lines and conventional varieties produced by selective breeding. A product assessed to be substantially equivalent is regarded as safe and fit for human consumption.

However, substantial equivalence can be claimed in advance, in which case subsequent risk assessment is most perfunctory. Furthermore, "substantial equivalence" does not mean equivalence to the unengineered plant or animal variety. The genetically engineered food could be compared to any and all varieties within the species. It could have the worst characteristics of all the varieties and still be considered substantially equivalent. It could even be compared to a product from a totally unrelated species or collection of species. Worse still, there are no defined tests that products have to go through to establish substantial equivalence. The tests are so undiscriminating that unintended changes, such as toxins and allergens, could easily escape detection. For example, a grossly altered genetically engineered potato with deformed tubers was tested and passed as substantially equivalent (Conner, 1995). Risk assessment based on the principle of substantial equivalence, in my view, is the stuff of farce. It is a case of "don't need - don't look - don't see." Biotechnology corporations are effectively given *carte blanche* to do as they please, while regulators are serving to diffuse and allay legitimate public fears and opposition (Ho and Steinbrecher, 1998).

It is significant that a lawsuit challenging the United States Food and Drug Administration (FDA) policy on genetically engineered foods has just been filed by a coalition of scientists, health professionals, religious leaders, and chefs demanding adequate safety testing and mandatory labeling. According to a press release issued by the International Center for Technology Assessment, the FDA policy is scientifically unsound and ignores significant health risks.

## *NOT* FEEDING THE WORLD

It is clear that no one needs genetically engineered foods, least of all peasant farmers in the Third World. "World hunger" is usually blamed exclusively on population increases in the Third World (Kendall et al., 1997; Food and Drink Federation, 1995; and Brown, 1998). Not mentioned are the large dam projects that continue to be supported by the World Bank. A total of 40,000 large dams already took 400,000 square kilometers of the best agricultural land out of production displacing 60 million farmers and further ruining vast areas of arable land by unsustainable irrigation practices that result in salination, waterlogging, drought and erosion (Goldsmith and Hilyard, 1984-92). At the same time, the policies of trade liberalization (WTO) enable corporations operating in the Third World to divert food-growing lands to non-food crops such as flowers and other luxury commodities, and to leisure complexes such as golf courses, turning traditionally food-exporting countries into importers (Cainglet, 1998). Over the past two years, 65 golf courses have been con-

structed in the Philippines alone, and the Government's own projections reveal that 1.5 million hectares of rice lands are to be converted into cash crops and golf courses. This is a country where 70 percent of the population are farmers, but the majority is landless, and less than one percent of the population controls more than 50 percent of all agricultural land. Those peasants still fortunate enough to own land have no more than two hectares. The Philippines has become a net importer of rice as a result, and the volume of import is set to grow. The same story is repeated all over the Third World, in Mexico, and in Russia.

Corporate interests are now offering genetic engineering agriculture to the Third World, with the World Bank as a major player (Kendall, et al., 1997). Far from feeding the world, genetic engineering agriculture, operating under the patents on life regime, will reinforce and intensify corporate control of food production and distribution, swelling the masses of displaced farmers, making the poor even poorer and hungrier.

Furthermore, in my view, it poses serious threats to food security, biodiversity, and human and animal health, and has the potential to unleash uncontrollable epidemics of drug and antibiotic-resistant infectious diseases. Those hazards are not teething problems, but inherent to the reductionist mindset of a bad science misguiding a hit-or-miss technology.

## THE BAD SCIENCE OF GENETIC DETERMINISM

Genetic engineering is a set of techniques for cutting, joining, modifying, and multiplying genes, especially for transferring genes from one species to another, most of which would never interbreed in nature. Thus, human genes are transferred to pig, mouse, fish, plants, and bacteria. And genes of all species can be recombined, cloned, and modified in any and every way. Genetic engineering is a new departure from conventional breeding techniques, and introduces new problems and dangers. But let us look first at the science motivating the technology.

This is what the public is told: “Research scientists can now precisely identify the individual gene that governs a desired trait, extract it, copy it, and insert the copy into another organism. That organism (and its offspring) will then have the desired trait” (Food and Drink Federation, 1995). This description is typical of literature supposedly promoting public understanding, and neatly encapsulates the bad science of genetic determinism. It gives the highly misleading impression of a precise technology, implying that:

- Genes determine characters in linear causal chains, one gene giving rise to one character;
- Genes are not subject to influence from the environment;
- Genes remain stable and constant;
- Genes remain in organisms and stay where they are put.

This is the most extreme version of the classical genetics that has dominated biology roughly from the 1930s up to the 1970s when genetic engineering began. It is so extreme that no biologist would admit to actually subscribing to it. But, why else would they suggest that by manipulating genes, practically all the problems of the world can be solved?

Genetic determinism goes counter to all the scientific evidence accumulated especially within the past 20 years, which gives us the new genetics. What is the new genetics of the present day really like (Ho, 1998)?

- No gene ever works in isolation, but in an extremely complicated genetic network where the function of each gene is dependent on the context of all the other genes in the genome. So, the same gene will have very different effects from individual to individual, because other genes are different. There is so much genetic diversity within any outbreeding population, such as human beings, that each individual is genetically unique. And, especially if the gene is transferred to another species, it is most likely, in my view, to have new and unpredictable effects.
- The genetic network, in turn, is subject to layers of feedback regulation from the physiology of the organism and its relationship to the external environment.
- These layers of feedback regulation not only change the function of genes but can rearrange them, multiply copies of them, mutate them to order, or make them move around.
- And, genes can even travel outside the original organism to infect another—this is referred to as horizontal gene transfer.

The new picture of the gene is diametrically opposite to the old static, reductionist view. The gene has a very complicated ecology consisting of the interconnected levels of the genome, the physiology of the organism and its external environment (Ho, 1998; Ho et al., 1998). Putting a new gene into an organism will create disturbances that can propagate out to the external environment. Conversely, changes in the environment will be transmitted inwards and may alter the genes themselves. Genetic engineering profoundly disturbs the ecology of genes at all levels, and that is where the problems and dangers arise.

## GENETIC ENGINEERING IS A CRUDE, IMPRECISE OPERATION

First of all, I must dispel the myth that genetic engineering is a precise operation. It is not. The insertion of foreign genes into the host cell genome is a random process not under the control of the genetic engineer. It is done by means of artificial vectors for horizontal gene transfer. Horizontal gene transfer is naturally done by infectious agents such as viruses and virus-like elements (plasmids and transposons) that are passed from cell to cell and from organism to organism, sometimes causing diseases including cancer, and spreading drug

and antibiotic-resistance genes. The gene(s) to be transferred are usually integrated into the genetic material of the vector; viruses can also transfer genes that are not integrated but are merely packaged within the protein coat that envelops the genetic material.

Species barriers limit natural agents, and all cells have mechanisms that break down or inactivate foreign genes. However, genetic engineers make artificial vectors for transferring genes by joining together parts of the most aggressive agents to overcome all species barriers. Most of the genes causing diseases are removed, but the antibiotic-resistance genes are left in. The gene to be transferred (transgene) is inserted into an artificial vector containing one or more antibiotic-resistance marker genes, which makes it possible to select for cells that have taken up the vector carrying the transgene. The vector carrying the transgene and marker gene(s) can either be replicated many times in the cell or become integrated into the genome, resulting in a transgenic cell from which a transgenic organism may be regenerated. The integration of the vector is random and not controllable by the genetic engineer (Walden et al., 1991).

This gives rise to correspondingly random genetic effects: inappropriate activation or inactivation of host genes, including, in my opinion, cancer (Doerfler et al., 1997). Recent studies document genetic disturbances that propagate far from the site of insertion of the foreign genes into the host genome (Parr, 1997). Furthermore, the foreign genes are equipped with very strong signals, most often from viruses, called promoters or enhancers, that force the organism to express the foreign genes at rates 10 to 100 times greater than its own genes. In other words, the genetic engineering process, both by design and otherwise, completely upsets the first two levels in the ecology of genes — the genome and the physiology — with dire consequences. It is my belief that the lines produced are unstable and are a threat to food security.

For every product that reaches the market, there are perhaps 20 or more others that have failed. However, even products that reach the market are failing:

- The FlavrSavr™ tomato was a commercial disaster and has disappeared (Fox, 1997).
- Monsanto's Bt-cotton, engineered with an insecticide from the soil bacterium *Bacillus thuringiensis*, failed to perform in the field in both US and Australia in 1996, and suffered excessive damages from Bt-resistant pests (Fox, 1997).
- Monsanto's 1997 Roundup Ready® cotton crops fared no better. The cotton bolls drop off when sprayed with Roundup and farmers in seven states in the US are seeking compensation for losses.
- The transgenic Innovator herbicide-tolerant canola failed to perform consistently in Canada. This has led the Saskatchewan Canola Growers Association to call for an official seed vigor test.

- Monsanto's entire Canadian genetically engineered rapeseed crop had to be recalled in 1997 because of "technical difficulties" (Monsanto Monitor, 1998).

Because genes respond to the environment; plants that perform in greenhouses may well fail in the field. But transgenic plants have additional problems.

There is widespread instability of transgenic lines, not only do they fail to perform consistently in the field, they generally do not breed true. In my opinion, transgenic lines are unstable because of the way they are made (see below).

## TRANSGENIC INSTABILITY

Traditional breeding methods involve crossing closely related varieties or species containing different forms of the same genes. Selection is practiced over many generations under field conditions so that the desired characteristics and the genes influencing those characteristics, in the appropriate environment, are tested and harmonized for stable expression over a range of genetic backgrounds. Different genetic combinations moreover will vary in performance in different environments. This "genotype-environment" interaction is well known in traditional breeding so it is not possible to predict how a new variety will perform in untested environments. In many cases, new varieties will lose their characteristics in later generations as genes become shuffled and recombined, or as they respond to environmental changes.

This problem is greatly exacerbated in genetic engineering. First of all, completely exotic genes are often introduced into organisms. Secondly, the procedures for creating transgenic organisms inherently generate increased genetic instability, In plants, the genes are often introduced into cells in tissue culture, and transgenic plants are regenerated from the cells after selection in culture.

- The tissue culture technique itself introduces new genetic variations at high frequencies; these are known as *somaclonal variations* (Cooking, 1989). In my view, that is because the cells are removed from the internal, physiological environment of the plant which, together with the ecological environment, keep gene expression, genes, and genome structure stable in the cells and the organism as a whole (Ho, 1998). Unilever used tissue culture techniques to regenerate oil palms for planting in Malaysia several years ago. This has now been abandoned as many plants aborted in the field or failed to flower (Perlas, 1995).
- The process of gene insertion is random and many secondary genetic effects can result, as mentioned earlier.
- The extra DNA integrated into the transgenic organism's genome disrupts the structure of its chromosome, and can itself cause chromosomal rearrangement (Wahl et al., 1984), further affecting gene function.

- The integrated vector containing the transgene(s) and marker gene(s) has the potential to move out again or reinsert into another site, causing further genetic disturbances (Ho, 1998; Ho and Steinbrecher, 1998; Walden et al., 1991; Doerfler et al., 1997).
- The highly mosaic character of most vector constructs make them structurally unstable and prone to recombination (Ho et al., 1998). This may be why viral-resistant transgenic plants generate recombinant viruses more readily than non-transgenic plants (see below).
- The use of aggressive promoters and enhancers to boost expression of transgenes stress and unbalance the physiological system and increases instability, as already stated.
- All cells have mechanisms that silence foreign genes (Finnegan and McElroy, 1994). One common mechanism is methylation — a chemical reaction that adds a methyl group to the base adenine or cytosine in the DNA (there are four bases in DNA, adenine, cytosine, guanine and thymine) — as the result of which, the gene is no longer expressed.

Transgene instability occurs both in farm animals (Colman, 1996) and plants (Lee et al., 1995). The transgenic sheep Tracy, engineered to produce human alpha-antitrypsin at high levels in her milk, failed to reproduce female offspring that match her performance. That is why cloning techniques that resulted in Dolly the sheep were contemplated. Much more is known about instability in plants. In tobacco, 64 to 92 percent of the first generation of transgenic plants become unstable. The frequency of transgene loss in *Arabidopsis* ranges between 50 and 90 percent. Instability arises during the production of germ cells and in cell division during plant growth. It can be triggered by transplantation or mild trauma (Parr, 1997).

Transgenic lines, therefore, often do not breed true. A typical case is the supposedly non-allergenic rice produced in Japan (Tada et al., 1996), which turned out to be both ineffective and unstable. The transgenic plants of the second and third generations showed only a 20 to 30 percent reduction of the allergens. The project has been abandoned (Devlen et al., 1995).

There is, in fact, no data documenting the stability of any transgenic line in gene expression, or in structure and location of the insert in the genome. Such data must include the level of gene expression, as well as a genetic map and DNA base sequence of the insert and its site of insertion in the host genome in each successive generation. No such data has ever been provided by industry, nor requested by regulatory authorities.

The instability of transgenic lines creates difficulties in quality control and traceability. It also raises serious safety concerns. A transgenic variety with a certain gene insert may be assessed safe, and completely change in characteristics when the insert moves to another position in the genome. Furthermore, one does not have to be prescient to see that transgenic instability makes

biotechnology unsustainable. It is my belief that it may ruin our agriculture and food supply just by being widely planted in place of nongenetically engineered and traditional, well-tried varieties. Small farmers in Third World countries will be especially vulnerable.

## DANGERS FROM NOVEL GENE PRODUCTS BOTH INTENDED AND UNINTENDED

Genetic engineering introduced new genes and gene products into our food chain, many from viruses and bacteria, which we have never eaten before and certainly not in such quantities. The viral "promoters" or "enhancers" that boost the expression of introduced genes continuously at a high rate essentially places them outside normal control. These promoters may also have further affects on host genes. As no gene in a normal organism is on at full blast all the time, the genetically engineered organism is under permanent metabolic stress which, in my opinion, makes it an unwholesome food.

More importantly, because no gene functions in isolation, the introduced genes are bound to interact with the host genes to give unintended effects, among which are, I believe, likely to be toxins and allergens. The most notorious case of unintended toxin is a batch of genetically engineered tryptophan, an amino acid widely sold in health-food stores. It killed 37 and made thousands ill. Graphic illustrations of "unintended effects" are failures in transgenic animals, which is disastrous for animal welfare (Mayeno and Gleich, 1994).

- The superpig engineered with human growth hormone gene turned out arthritic, ulcerous, blind and impotent (Cox, 1996).
- The supersalmon engineered to grow as fast as possible ended up with big monstrous heads and died from not being able to breathe or feed properly (*GenEthics News*; Devlen et al., 1995a).
- The latest clones of the sheep Polly are abnormal and eight times as likely to die at birth compared with ordinary lambs (Devlen et al., 1995b).

And it is possible that the carcasses of failed transgenic experiments and xenotransplant pigs could turn up as meat on our dinner table. They have already been approved for sale by the US Department of Agriculture (USDA) in 1994, without being labelled as such. They will all pass as "substantially equivalent". And if not, then GRAS, Generally Regarded As Safe, according to the standards set by the FAO/WHO food safety report (FAO/WHO, 1996)

## THREATS TO BIODIVERSITY

Agricultural biotechnology is already posing unacceptable threats to biodiversity, not surprisingly because wider ecological impacts are ignored by the reductionist science.

- Broad-spectrum herbicides used with herbicide-tolerant transgenic crops, such as glufosinate (Mendelson, 1998) (Novartis' Basta) and glyphosate (Cox, 1996) (Monsanto's Roundup) destroy plants indiscriminately, many of which are habitats for wildlife. They are toxic to animals and human beings. Glufosinate also causes birth defects and glyphosate is mutagenic (Cox, 1995).
- Transgenic plants with insecticidal transgenes not only harm beneficial species directly, but also indirectly down the food chain, such as lacewings and ladybirds feeding on prey species that have eaten transgenic plants (Kale, et al., 1995) and Birch, et al., 1997). In a field trial of Bt-cotton in Thailand, 30 percent of the bees around the test fields died (Hilbeck et al., 1997).
- Transgenic crops with insecticidal genes or herbicide tolerant genes actually favour the widespread mutation to resistance (Ho, 1998). In other words, they exacerbate the problem they are supposed to solve.

Pesticide resistance and herbicide tolerance are not due to the natural selection of pre-existing, rare random mutations, as we have been told in textbooks for years. They are due to genetic mutations that can occur in not all of the individuals in the populations in response to sublethal levels of the pesticide or herbicide. So, just as pesticidal transgenic plants, in my opinion, lead to rapid evolution of resistance among pests, the use of herbicide-tolerant transgenic plants will, I believe, also result in the widespread evolution of herbicide tolerance among weeds, even in the absence of cross-pollination. (The spread of transgenes by cross-pollination has already been demonstrated.) This has been known more than 10 years (Hyrien and Buttin, 1986). The genetic changes are part and parcel of the physiological mechanisms common to all cells and organisms challenged with toxic substances, not only pesticides and herbicides (Mikkelson, et al., 1996), but also anti-cancer drugs in mammalian cells and most dangerously, antibiotics in bacteria (Ho, 1998; Ho et al., 1998).

The use and abuse of antibiotics in intensive agriculture and conventional medicine have been responsible for the evolution of antibiotic resistances in pathogens. But, here is the final straw. Genes do not stay where they are put, but can travel horizontally between species that do not naturally interbreed.

## Genetic engineering organisms contribute to drug and antibiotic-resistant infectious diseases

As previously mentioned, genetic engineering involves transferring genes horizontally between species that do not interbreed. While natural agents are limited by species barriers, genetic engineers make artificial vectors for transferring genes by joining together parts of the most aggressive agents to overcome all species barriers.

Artificial vectors and the genes they carry have the potential to spread horizontally to a wide range of species, to recombine with their genes to generate new viral and bacterial pathogens. This very danger had made the first molecular geneticists impose a moratorium on genetic engineering in the Asilomar Declaration of 1975 (Hyrien and Buttin, 1986). But commercial pressures soon intervened. Activities resumed after regulatory guidelines were put in place and commercial production began. Were those guidelines adequate? No, not in the light of recent scientific evidence as eight scientists including myself argue in a new report (Ho et al., 1998).

There has been a resurgence of infectious diseases within the past 20 years, diseases that are resistant to treatment by drugs and antibiotics. A public health crisis is looming worldwide. Infectious diseases are responsible for one-third of the 52 million deaths from all causes. Multi-drug-resistant tuberculosis is now estimated to affect 10 million each year with 3 million deaths. At least 50 new viruses attacking humans emerged between 1988 and 1996. Between 1986 and 1996, *E. coli* O157:H7 infections increased by 10-fold in England and Wales and 100-fold in Scotland. Vancomycin resistance rose from 3 percent to 95 percent in San Francisco hospitals in the four years between 1993 and 1997. And strains of dangerous bacteria including *Staphyloccocus aureus* (toxic shock syndrome), *Enterococcus faecalis* (blood poisoning and wound infection), *Pseudomonas aeruginosa* (blood poisoning and pneumonia) and *Mycobacterium tuberculosis* (TB) are invulnerable to all known antibiotics (Walden et al., 1991; Dobson, 1998).

Over the past three to four years, geneticists have discovered how horizontal gene transfer and recombination are responsible for generating the new viral and bacterial pathogens and spreading drug and antibiotic resistance genes (Ho, 1998; Ho et al., 1998). Are we unleashing widespread, cross-species epidemics that will be impossible to control? The signs are that the worst case scenario, predicted by the Asilomar Declaration, may already be with us as the result of 20 years of commercial gene technology.

Can transgenic plants and animals contribute to such processes? Yes. They can. Transgenic plants have been found to transfer their transgenes and antibiotic resistance marker genes to soil fungi and bacteria (Gainglet, 1998; Hoffman et al.; Schluter et al., 1995). Plants engineered with a viral gene, supposed to resist virus attack, actually have increased propensity to generate new, superinfectious viruses by recombination (Gebhard and Smalla, 1998; Vaden and Melcher, 1990; Lommel and Ziong, 1991; Greene and Allison, 1994; Wintermantel and Schoelz, 1996). Genetic engineering, by enhancing horizontal gene transfer and recombination, may, I believe, be greatly multiplying the odds for generating new viral and bacterial pathogens and spreading drug and antibiotic resistance genes.

The regulatory guidelines set up after Asilomar were based largely on assumptions, practically every one of which has been overturned by recent scientific findings (Ho, 1998; Ho et al., 1998).

- Biologically "crippled" laboratory strains of bacteria can often survive in the environment, or go dormant but continue to exchange genes with other organisms (Jager and Tappeser, 1996).
- Routine chemical inactivation methods may leave up to 10 percent of viruses and other pathogens in an infective state (Coghlan, 1997).
- Legal limits of "tolerated releases" from contained use vastly exceed the minimum infective dose of some pathogens: 10,000 colony-forming units/ml in air or water (Novo Nordisk) versus a minimum infective dose of 50 bacteria for *E. coli* O157:H7 (Smith, 1997)
- Antibiotics increase the frequency of horizontal gene transfer 10 to 10,000-fold (Lorenz and Wackernagel, 1994; Davies, 1994).
- DNA released from dead and living cells persist in the environment and transfer to other organisms (Sandaa and Enger, 1994; Yin and Stotzky, 1997).
- Naked viral and vector DNA may be more infectious, and have a wider host range than the virus (Traavik, 1995).
- Viral DNA resists digestion in the gut of mice; enters the blood stream to infect white blood cells, spleen and liver cells; and integrates into the mouse cell genome (Ho et al., 1998; Schubbert et al., 1994; Schubbert et al., 1997).

## CONCLUSION

In conclusion, genetically engineering agriculture is unnecessary and unethical. It is based on science that is unsound, and the foods produced are, in my opinion, unwholesome. It is unsustainable because the technology is hit or miss. Most of all I believe it is inherently unsafe.

Erwin Chargaff, a founding father of molecular biology, warned that all innovation does not result in "progress." He once referred to genetic engineering as "a molecular Auschwitz" and warned that the technology of genetic engineering poses a greater threat to the world than the advent of nuclear technology. "I have the feeling that science has transgressed a barrier that should have remained inviolate," he wrote in his autobiography, *Herculean Fire*, ". . . you cannot recall a new form of life . . . It will survive you and your children and your children's children. An irreversible attack on the biosphere is something so unheard of, so unthinkable to previous generations, that I could only wish that mine had not been guilty of it."

In the face of the wealth of existing scientific evidence and the precautionary principle, the least our governments could do is to impose a five-year moratorium and to support independent scientists to go back to basic research on

the legitimate, sustainable, and safe uses of the technology. At the same time, there should be a major public inquiry in which the scientific, social, and moral issues are considered together and openly debated. Most of all, we need to seriously rethink where the priorities are, and the sort of life we want as a civil society.

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