GENETIC MODIFICATION AND FRANKENSTEIN FOODS

THE ECOLOGICAL RISKS OF GENETIC ENGINEERING IN AGRICULTURE

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For 10,000 years agriculture has been based on the strategy of conserving and enhancing genetic diversity. Humans have always this time domesticated and modified wild plants and animals, the gifts of nature's biodiversity. According to Erna Bennett (former genetic resources expert to the Food and Agricultural Organization of the UN), 'The patchwork of cultivation sown by man unleashed an explosion of literally inestimable numbers of new races of cultivated plants and their relatives' (Hawkes, *Conservation and Agriculture,* 1978).

Prior to planting crops, humans harvested wild plants. For example, corn, rice and wheat, were originally collected from the wild. For gathering societies, less than a month of harvesting from the wild could ensure enough for the year's needs. For reasons unknown to us, human societies moved from harvesting wild grain to domesticating and sowing the seeds of those grains. This is a process that still continues. A farmer participating in the Indian Seed-Saving Movement, Navdanya, which is dedicated to conserving native biodiversity, domesticated a wild rice in 1998.

Domestication changed the nature of plants. As Cary Fowler and Pat Mooney have described in their book, *Shattering*, "The simple act of harvesting seeds of non-domesticated plants and then sowing them produced remarkable changes of great advantage to people. Weeds and grass, as everyone knows, are extraordinarily adapt at spreading their seeds. The survival of such plants depends on their ability to spread their seeds ...

The unavoidable collection of non-shattering types caused the first fields planted by the first farmers to be constituted primarily of grasses significantly different in one respect from those that grow wild. Repeated sowings of these seeds produced non-shattering plants - plants whose seed or grain would remain on the plant even if jostled by the emerging farmer with a flint-bladed sickle. Genetically, the change was simple. Often the difference between shattering and non-shattering types is caused by just one or two genes, the biological barriers of heredity. With non-shattering grains, people were able to harvest a greater percentage of all the seeds in the field. Harvested yield increased, giving these first farmers positive response for their efforts".

Farmers selected, improved, evolved crops and seeds over the centuries and created the tremendous diversity of crops and cultures that have nourished the world. Crops were bred for resistance to drought and resistance to water logging, for surviving salinity and frost. The first generation plants bred for domestication was based on farmers knowledge, on the principle of diversity, and on working with nature.

The Green Revolution

The second generation of plants bred for agriculture came to be known as the Green Revolution. The crossbreeding of different varieties to make them more resistant to chemicals was a departure from the earlier centuries of plant breeding based on farmers' knowledge. Firstly, the farmer was displaced by professional breeders. Secondly, ecological processes of food production were replaced by ecologically destructive methods, such as intensive use of water and of synthetic chemicals. Industrial breeding also destroyed the genetic diversity of crops as monocultures of industrially bred seed spread worldwide into ecosystems for which they were not adapted.

Linked to the centralized strategy for breeding 'voracious varieties' of seeds (those that consume high levels of fertilizers and water) was the need for uniformity and the destruction of diversity. Uniformity became imperative from the view of centralized production of seeds as well as centralized provision of seeds as well as centralized provision of inputs like water and fertilizers.

Released in Japan in 1935, a wheat known as Norin was a cross between a Japanese dwarf wheat and an American wheat that the Japanese government had imported from the USA in 1887. Norin was brought to US in 1946 by Dr. D.C. Salmon, an agriculturist acting as a US military adviser in Japan, and further crossed with an American of the variety by US Department of Agriculture scientist Dr. Orville Vogel. Vogel sent the strain in the 1950s to CIMMYT, the international maize and wheat centre in Mexico. There it was used by Norman Borlaug, who was on the Rockfeller Foundation staff, in nine years of experimenting, to develop his well-known Mexican varieties. Of the thousands of dwarf seeds created by Borlaug, only three went on to create the Green Revolution wheat plants that were spread worldwide. On this narrow and alien genetic base the food supplies of millions are precariously perched.

Global rice monocultures were created by sending seeds across the world from the International Rice Research Institute (IRRI). The first release, IR-8, was a cross between the Indonesian variety and a dwarf strain from Taiwan. The various IR-varieties were prone to pests and diseases owing to monocropping and a narrow genetic base, which meant that in turn more toxic pesticides would be required. This environmental cost was justified on the grounds of increasing food production.

The new seeds were called high yielding varieties, or miracle varieties that would make possible the end of hunger and famine. However, the dwarf gene was essential to the technological package of the Green Revolution, which was based on intensive inputs of chemical fertilizers. The taller traditional varieties tended to convert the fertilizers into overall plant growth whereas the shorter, stiffer stems of dwarf varieties allowed more efficient conversion of nutrient into grain. The connection between chemical fertilizers and dwarf varieties that were established through the breeding programmes of CIMMYT and IRRI, created a major shift in how seeds were perceived and produced, and who controlled the production and use of seeds.

The Green Revolution varieties were not intrinsically higher yielding than the farmers' varieties that they displaced, nor did the industrial monocultures provide more food than diversified, ecologically managed small farms. In a 15 nation study of the impact of the seeds (UN Research Institute for Social Development), Dr. Palmer concluded that the term 'high-yielding varieties' (HYVs) is a misnomer since it implies that the new seeds are high-yielding in themselves. Their distinguishing feature is, in fact, that they are highly responsive to certain key inputs such as fertilizers and irrigation. Palmer therefore suggested the term 'high-responsive varieties' (HRVs) in place of 'high yielding varieties' (HYVs) (quoted in Lappé and Collins, *Food First,* 1982). The gain in yield is insignificant compared to the increase in inputs.

The measurement of output is also biased by restricting it to the marketable part of crops, and to the yield of individual crops. Food is necessary not only for people. Ensuring adequate organic matter to feed animals and the soil is essential for sustainable agriculture. In dwarf varieties grain is increased at the expense of straw production, so output is affected in two dimensions - food is diverted from other species, and ecological cycles that maintain soil fertility and food production for the future are also destroyed.

Gene Transfer and Jumping Genes

Genetic engineering in agriculture has often been called the second Green Revolution. Genetic Engineering does in fact accelerate the Green Revolution trends towards the spread of chemicals, the expansion of monocultures and the destruction of agrobiodiversity, but in addition creates risks of genetic pollution or biopollution.

While it is true that humans have been modifying plants from the beginning of agriculture, it is not true that all modifications are ecologically equivalent and have similar impact. Modifications introduced by farmers were different from hose of the industrial breeders of Green Revolution varieties. The former increased biodiveristy, the latter reduced it.

The modifications introduced by genetic engineers are different again. These organisms result from mixing species that would not normally mix in nature. New ecological risks arise from the possibilities of moving genes across organisms to create 'transgenic' organisms. The ecological structure, function and impact of these novel organisms on other species, on the environment and on human health is therefore different from wild or conventionally bred relatives.

Genes are functional units formed by sequences of a molecule called DNA (deoxytibose nucleic acid) and are considered the unit of heredity in all living organisms. The structure of DNA was first identified by James Watson and Francis Crick who showed it to be a double helix. Strings of DNA are called chromosomes. All living organisms are made of cells, and each cell has a nucleus in which strings of DNA are organized as chromosomes. When fertilization occurs in animals or plants, there are two sets of chromosomes that pair in the embryonic cell - one inherited from the female parent, the other from the male. The cells formed on fertilization continue to divide and multiply, and the genetic material in each new cell is identical.

There are two paradigms of the role and function of genes in living organisms - the reductionist and the non-reductionist. According to the reductionist paradigm, genes are the blue print of life, the master molecule that determines the structure and function of living organisms. In this paradigm, genes act independently of other genes, the rest of the organism and the environment.

As non-reductionist biologists stress, genes act in context and in relationship to other parts of the organisms and to other organisms and the environment. Crick and Watson explained how DNA can encode information, replicate and mutate. However, to leap from the local functions of genes defined by individual proteins to complex functions of living organisms is unjustified. This extended theory of the gene as the basis of life is being questioned by leading biologists who take the ecology of the gene and the ecology of the organism into account. Unfortunately, precisely at the time when scientists are questioning genetic reductionism, reductionism is becoming the basis of the new biotechnologies, the new life sciences industry and the new genetic commerce. Genetic engineering allows DNA to be moved across species boundaries, with the idea of introducing particular traits. As Brian Goodwin, one of the world's leading theoretical biologists makes clear:

"The assumption is that a characteristic can be transferred from one species to another simply by moving the gene. The problem is that genes are defined by context. For example, a gene that in a mouse produces a hormone regulating growth will have one effect in the mouse, but the same gene producing the hormone in a human being will have a very different effect. So as we move genes from one species to another, we will keep getting unpredictable effects which simply could not have been anticipated" (Quoted in Suzuki, *From Naked Ape to Super Species,* 1999).

In spite of the growth of theoretical insights and empirical evidence supporting the non-reductionist approach to genes, genetic, determinism is still powerful — mechanistic praradigms have been the legacy of the first Industrial Revolution, and reductionism serves industry well. Reductionist biologists have gone far in raising the gene above the organism and demoting the organism itself to a mere machine. The purpose, the sole purpose of this machine is its own survival and reproduction, or perhaps to put it more accurately, the survival and reproduction of the DNA that is said both to programme and to 'dictate' its operation. In Richard Dawkin's terms, an organism is a 'survival machine' - a 'lumbering robot' constructed to house genes, those 'engines of self-preservation' that have as their primary property inherent 'selfishness'. They are sealed off from the outside world, communicating with it by tortuous indirect routes, manipulating it by remote control. They are in you and in me; they created us, body and mind; and their preservation is the ultimate rationale for our existence" (Dawkins, *The Selfish Gene,* 1976).

In the mechanistic, reductionist model, the building blocks are atoms or substances or matter. Genes have no internal relations. They are the nuts and bolts that make a machine. Nuts and bolts cannot evolve, they can merely be rearranged. In biology the mechanistic model has taken genes to be the atoms that constitute living systems. In this billiard ball model, the genes are assumed to be particles located on chromosomes. The genes make proteins, proteins make us, and the genes replicate themselves. In 1926, *The Gene as the Basis of Life* biologist H.J. Muller wrote that the gene can be viewed as a biological atom, solely responsible for the physiological and morphological properties of life forms.

Reductionism was promoted strongly by the biologist August Weismann, who nearly a century ago postulated the complete separation of the reproductive cells - the germ line - from the functional body, or soma. According to Weismann reproductive cells are already set apart in the early embryo, and they continue their segregated existence into maturity, when they contribute to the formation of the next generation. This supported the non-heritability of acquired traits with no direct feedback from environment to heredity.

The reductionist assumption that genes are 'atoms' of life and determinants of properties of life forms is linked to the assumption that information only flows in one direction from genes to organisms. This genetic determinism was reinforced by the emergence of molecular biology and the discovery in the 1950s of the role of nucleic acid. Molecular biology showed a means of transferal of information from genes to proteins, but gave no indication, until recently, of any transfer in the opposite direction. The inference that there could be none became what Francis Crick called the 'central dogma' of molecular biology: 'Once information has passed into proteins, it cannot get out again'.

Isolating the gene as a 'master molecule' is part of biological determinism. The 'central dogma' that genes as DNA make proteins is another aspect of this determinism. This dogma is preserved even though it is known that genes 'make' nothing and that the complex living organism in complex relationship with the environment is what `makes' living systems.

The non-reductionist view of genes and living systems locates genes in the ecological complexity of organisms. As Richard Lewontin, the molecular biologist has stated:

"DNA is a dead molecule, among the most non-reactive, chemically inert molecules in the world. It has no power to reproduce itself. Rather, it is produced out of elementary materials by a complex cellular machinery of proteins. While it is often said that DNA produces proteins, in fact proteins (enzymes) produce DNA.

When we refer to genes as self-replicating, we endow them with a mysterious autonomous power that seems to place them above the more ordinary materials of the body. Yet if anything in the world can be said to be self-replicating, it is not the gene, but the entire organism as a complex system" (*The Doctrin of DNA,* 1993).

According to biologist Mae Wan Ho in Genetic Engineering: Dream or Nightmare? (1997), there are three assumptions of the reductionist paradigm:

- Genes determine character in a straight-forward additive.
- Genes and genomes are stable, and except for rare random mutations, are passed on unchanged to the next generation.
- Genes and genomes cannot be changed directly in response to the environment.

None of these assumptions is true. Genes code for the thousands of metabolic reactions that provide the energy to do everything that constitutes being alive. These metabolic reactions form an immensely complicated network in which the product of our enzyme is processed by one or more other enzymes. Thus, no enzyme (or gene) ever works in isolation. Consequently, the same gene will have different effects from individual to individual because the other genes are different. The complicated network of interactive processes that connects different sub-systems of a living organism is the real source of determining traits and properties of plants and animals.

This intricate network also responds to the environment. Barbara McClintock, who won the Nobel Prize in 1983 for her work on jumping genes, is of the opinion that, 'The functioning of genes is totally dependent on the environment in which they find themselves. The term 'jumping genes' indicates that genomes are not stable but fluid and dynamic. Genes are not isolated atoms, unchanging and ummutable, but flexible and interactive, and their behavior is influenced by the larger networks within the genome and by the larger environment. But although the reductionist paradigm has given way to the non-reductionist paradigm in basic research, reductionism still guides genetic engineering.

What is Genetic Engineering?

Genetic engineering is the set of techniques, also referred to as recombinant (rDNA) technology, which is used for modifying and recombining genes from different organisms that would not naturally interbreed. Examples of transgenic oganisms are:

- The introduction of flounder genes into strawberries for longer storage and larger travel distances on the assumption that the gene that allows flounders to survive in icy cold water would preserve strawberries.
- The introduction of hamster genes into tobacco to increase sterol production (which enhances the effect of the nicotine).
- The insertion of spider genes into goats to enable them to produce silk in their milk.
- The insertion of human genes into sheep to produce 'human' proteins in their milk.
- The introduction of human sperm-producing genes into rats to produce 'rat-man sperm' to fertilize human eggs. (*Dessee*, 'Unnatural Selection', *Wild Duck Review,* Summer 1999)

There are two principle methods of transferring foreign genes into crop plants. The first is to use bacterial or viral vectors to carry genes into a plant's genome. The second is the direct transfer of DNA using gene guns or microprojectiles.

Introducing foreign genes through bacterial or viral infections involves a number of steps. The first is to make recombinant DNA in test tubes by using enzymes (catalysing proteins) isolated from micro-organisms to cut and join together pieces of DNA from different organisms. The genes are multiplied and then transferred into plants through 'vectors', which are usually viruses or plasmids (the small circular DNA structure in bacteria). Once inside the cells, the vectors with the transgene became a permanent part of the organism. Transgenic organisms are organisms that have been 'infected' by transgenes using vectors.

The most common vectors are combinations of natural genetic parasites and infective agents, including viruses that cause diseases in plants and animals, with their pathogenic functions 'crippled'. The vector used most widely is derived from a tumour-inducing plasmid carried by the soil bacterium *Agrobacterium tumefacious*. These bacteria naturally infect over one hundred plant species, and genetic engineers make use of this quality. But the gene-transfer method using *Agrobacterium* is a labour intensive and is unsuitable for cereal crops such as rice, wheat and maize since it does not naturally infect their species.

This limitation has been overcome by direct transfer methods using particle bombardment through 'gene guns' or 'gene cannons'. These methods were developed independently by John Saiford and colleagues at Cornell, & Dennis McCake and colleagues at Agracetus Company, U.S., now owned by Monsanto. In the Biological Ballistics or 'Biolistic' method evolved at Cornell, magnesium tungsten or gold particles are coated with DNA and literally blasted into plant cells using a gunpowder detonation in a particle gun. The particles carrying DNA are accelerated at high velocity, enter the cell wall, and transfer the DNA. The Dupont Company has exclusive rights to use Cornell's patented Biolistic Gene Gun for developing commercial transgenic crop seed (Nottingham, *Eat your Genes,* 1998). Agracetus' (or Monsanto's) 'Accell' method uses electrical discharge to propel accelerated DNA-coated gold particles into plant material. In 1988 Agracetus (now owned by Monsano) was the first company to transfer foreign genes into soya beans and Monsanto's Roundup Ready soya beans were developed using the Agracetus technology.

Transgenic plants produced either by introducing foreign genes through vectors or through particle bombardment have a low rate of success. To separate plants that have incorporated the foreign gene from those that have not, antibiotic resistance markers have to be used. Genetically engineered plant cells are then grown in a medium containing this antibiotic. Those that survive are the ones that have taken up the transgene with the antibiotic resistant marker attached. These are then cultured and grown into mature plants.

No matter how the transgene is introduced, there is total lack of predictability about the exact location in the chromosome where the gene is inserted. The common argument that genetic engineering is precise and predictable is not true. It is in fact not 'engineering' at all. The theoretical biologist Stuart Newman, interviewed for *Wild Duck Review* (Summer, 1999) said, "It is hit or miss production of potentially useful monstrosities, Genetic engineering does not qualify for the status of a technology and is in fact being commercialized prematurely".

As Terje Traavik, a leading molecular biologist, states:

"Technology; is derived from the Greek term 'tekhne' which is connected to handicraft or arts. Our associations with the word include predictability, control, and reproductibility. The parts of genetic engineering that concerns construction of vectors are truly technology. But present time techniques for moving new genes into cells and organisms mean:

- No possibility to target the vector/transgene to specific sites within the recipient genomes. In practical terms this means that modifications performed with identical recipients and vector gene constructs under the same standardized conditions may result in highly different GMOs depending on where the transgenes become inserted.
- No control with changes in gene expression patterns for the inserted or the endogenous genes of the GMO.
- No control of whether the inserted transgene(s), or parts thereof, move within or from the recipient genome, or where transferred DNA sequence end up in the ecosystems.

In the light of this, it seems both pertinent and relevant to ask the question whether genetic engineering at its present level of development deserves the label 'technology' at all" (Terje Traavik, *An Orphan in Science,* 1999).

The promoters of genetic engineering state that genetic engineering is no different from conventional breeding, and hence poses no new health or ecological risks. They also argue that it is more precise and predictable than conventional breeding. But conventional breeding does not transfer genes from bacteria and animals to plants. It does not put fish genes into potatoes or scorpion genes into cabbage. It crosses rice with rice, and wheat with wheat. Genetic engineering differs from conventional breeding for the following reasons:

1. Unlike conventional breeding, genetic engineering recombines genetic material from different unrelated species which do not interbreed in nature and for which there is no, or very little, probability of natural progeny. This has unpredictable effects on the physiology, biochemistry and ecological functions of the transgene organisms.

2. New exotic genes are introduced into unpredictable locations in the genome, while conventional breeding shuffles different versions of the same genes whose genome structure has been given by evolution. Introduction of exotic genes in unpredictable ways can lead to unpredictable effects on the metabolism, physiology, and biochemistry of the recipient transgene organism.

3. Genetic engineering uses vectors which are derived from disease – causing viruses and plasmids. Since these vectors are designed to shuttle genes between a wide range of species, they have a wide host range, and can infect a wide range of plants and animals. Further, since vectors are constructed to overcome the recipient organisms' defense mechanisms against invasion by foreign DNA, genetic engineering carries the risk of reducing resistance and immunity and making plants more vulnerable to infections.

The Spread of GE crops

The most significant spread of crops from genetic engineered seed is in the U.S.A. Worldwide more than 28 million hectares (70 million acres) have been planted with genetically engineered seed. Of this, 71 per cent is accounted for by herbicide-resistant soya bean, corn and cotton. Thousands of acres have also been planted with accidentally contaminated seeds.

The commercialized staple food crops that are genetically engineered are currently only three in number: soya bean, corn, canola. The trends in cultivation of transgenic crop show that genetic engineering is displacing the diverse foods that people of diverse cultures have used in their diets. Cropping systems for GMOs are based on expanding monocultures of the same variety evolved for single-function response. In 1996, 769,000 hectares (1.9 million acres) were planted with only two varieties of Bt.cotton (genetically engineered to produce the pest-killing toxin of the organism *Bacillus thuringiensis*) and 526,000 hectares (1.3 million acres) with the same Roundup Ready Soya bean. As the Biotechnology industry globalizes, these monoculture tendencies will increase, further displacing agricultural biodiversity and creating ecological vulnerability.

The Green Revolution narrowed the basis of food security by displacing diverse nutritious food grains and spreading monocultures of rice, wheat and maize, but it did focus on staple foods and their yields. The Genetic Engineering Revolution is undoing the narrow gains of the Green Revolution both by neglecting the diversity of staples and by not addressing the issue of yields. Yield increase does not even exist in the list of traits being introduced into transgenic crops. Fifty four per cent of the increase in transgenic crops accounted for by herbicide-resistance which implies increased use of herbicides, not increased food. As an industry briefing paper (James, *Global Status of Transgenic Crops in 1997*) accepts, 'The herbicide tolerant gene has no effect on yield *per se*'.

There are two main justifications for the spread of genetic engineering in agriculture. The first is that it will increase yields and will contribute to food security. The second is that it will reduce the use of chemicals and will contribute to sustainable agriculture and the protection of the environment. However, both are without foundation. Genetic engineering will in fact increase food insecurity, not reduce it. It will also increase pollution, both by spreading the use of agrichemicals and by creating new risks of biopollution. Also used to promote GM foods is the myth of their safety on the grounds that they are ‘substantially equivalent’ to conventionally produced food. I challenge these three myths and aim to show that biotechnology in food and agriculture is characterized by the following realities:

- that genetic engineering, like the Green Revolution, will create hunger by destroying the livelihoods and resources of the poorest two-thirds of humanity;
- that genetic engineering poses a threat to the planet both by increasing chemical use and by destroying biodiversity;
- that by the biotechnology industry itself, GMOs are claimed as ‘novel’ and hence *not* substantially equivalent to conventional crops.

In addition, scientific evidence about the risks of genetic engineering is growing.

The Myth of Feeding the World

The biotechnology industry argues that no other technology can increase food production as efficiently as industrial breeding and biotechnology. However, this argument is flawed:

- Industrial breeding focuses on partial yields of single crops rather than total yields of multiple crops and integrated systems.
- Industrial breeding focusses on yields of one or two globally traded commodities, not on the diverse crops that people eat.
- Industrial breeding focusses on quantity per acre rather than on nutrition per acre.
- Industrial agriculture has very low productivity judged on the basis of resource use.
- Industrial agriculture undermines food security by using up resources that could have been used for sustainable food production.

A 1998 report on a study by the Rural Advancement Foundation International (RAFI) states:

"Of some 320,000 vascular plants, about 3,000 species (both 'wild' and domesticated) are regularly exploited as food, while the total number of plant species cultivated and collected by humans exceeds 7,000. A recent study by Canadian researchers, Christine and Robert Prescott-Allen, used *per capita* food supply data from 146 countries and found that 103 species contribute 90% of the world's plant food supply. However, thousands of species contribute to the food supply of the other 10% which have considerable importance from a nutritional viewpoint and for poor people".

Ecological alternatives can increase food supply through biodiversity intensification instead of chemical intensification and genetic engineering.

The global trends of genetically engineered crops is seen in the table below. The commercialized staple food crops that are genetically engineered are currently only three in number. In place of hundreds of legumes and beans eaten around the world, there is only soya bean. In place of diverse varieties of millets, wheat and rice there is only corn. In place of the diversity of oil seeds there is only Canola. The trends in cultivation of transgenic crops show that genetic engineering is displacing the diverse foods that people of diverse cultures have used in their

Global area of transgenic crops 1996-97

40%	soya bean
25%	corn
13%	tobacco
11%	cotton
10%	canola
1%	tomato
1%	potato

diets. Its focus is on non-food commercial crops like tobacco and cotton and on crops like soya bean which before were not staples for most cultures outside East Asia. Transgenic tobacco, cotton, tomato are not food staples and will not feed the hungry. Food security has cultural dimensions, and soya bean will not provide food security for dal-eating Indians, nor corn for the sorghum belt of Africa.

The Myth of High Yields

Diverse farmers' varieties of food crops have been replaced by the supposed high-yielding varieties (HYVs). These HYVs have been bred only to yield enhanced grain production, that is, a high *partial* yield. They exhibit low total *system* yield. HYVs fail to produce enough straw that is adequate in quality or quantity to feed livestock or soils. The increase in marketable output of grain has been achieved at the cost of decrease of biomass for animals and soils and of the decrease of ecosystem productivity due to overuse of resources. Indigenous varieties outperform HYVs in *total system* yield. When the total biomass (grain plus straw) is taken into account, traditional farming systems based on agriculture varieties are not found to be low-yielding. In fact many native varieties have higher yields both in terms of grain output as well as of total biomass output than the supposed HYVs that have been introduced in their place.

While these reductionist categories of yield and productivity allow a higher measurement of yields, they exclude the measurement of the ecological destruction that affects future yields. Productivity in traditional farming practices has always been high if it is remembered that very little external inputs are required. While the Green Revolution has been projected as having increased productivity in the absolute sense, when resource-utilization is taken into account, it has been found to be counterproductive and resource-inefficient (*Starving the Four Billion and Destroying the Planet',* RFSTE briefing paper for the Convention on Biodiversity, May 1997).

The increased yields from genetically engineered crops is the most important argument used by the genetic engineering industry. However, genetic engineering has actually led to decline in yields. Bill Christianson, a U.S. soya bean farmer at the first conference on "Biodevastation" at St. Louis, Missouri, the Headquarters of Monsanto, in July 1998, said that in Missouri, genetically engineered soya had a five bushel per acre decrease in yield. Ed Oplinger, Professor of Agronomy at the University of Wisconsin, has been carrying out yield trials on soya bean for 25 years. On the basis of data he collected in 12 states which grow 80 per cent of the U.S. soya, he found genetically engineered soya beans had 4 per cent lower yields than conventional varieties (Holzman, *Genetic Enginering News,* April 1999).

In a study done by Marc Lappe and Britt Bailey, in 30 out of 38 varieties conventional soya beans outperformed the transgenic ones, with an overall drop in yield of 10 per cent compared conventional varieties (Against the Grain, 1999). Dr. Charles Benbrook reported a 6.7 per cent decline in yields in soya beans engineered for resistance to the herbicide Roundup on the basis of 8,200 university-based varietal trials in 1998. 'If not reversed by future breeding enhancements, this downward shift in soya bean yield potential could emerge as the most significant decline in major crop ever associated with a single genetic modification.' (*Ag Biotech Info Net Technical Paper,* 13 July 1999).

Rodney Garrison was among the U.S. farmers who believed in Monsanto's miracle Roundup Ready cotton, a cotton variety resistant to Monsanto herbicide Round-up. However, in the Mississipi delta where he farms, officials are warning farmers to hold off until further testing. Dozens of farmers are seeking millions of dollars in damages from Monsanto and its partner Delta-Pine arising from cotton boll damage in the 1997 Roundup Ready cotton harvest, perhaps caused by the genetic structure. Farmers have lost upto 40 per cent of their crop. The

Mississippi Seed Arbitration Council ruled that Monsanto's Roundup Ready cotton failed to perform as advertised, and recommended payments of nearly $2 million to three cotton farmers who suffered severe loses.

Bacillus thuringiensis (Bt.) is a naturally occurring organism which produces a toxin. Genes for Bt. toxins are being added to a wide range of crops to enable the plants to produce their own insecticide. In the first trials of Bt. cotton undertaken in India, the yields were sometimes dramatically lower than that of non-Bt. cotton.

The Myth of Decreased Chemical Use

In pushing genetic engineering, chemical corporations have used various strategies to make the public believe that biotechnology in agriculture implies the end of chemical hazards and that it 'protects the planet' (International Association of Plant Breeders, *Feeding the Eight Billion and Preserving the Planet,* 1998). But there are four reasons why biotechnology will lead to an increase in chemical use:

- The predominant application of genetic engineering in agriculture is in growing crops resistant to specific herbicides. This will increase rather than reduce herbicide use.
- The use of chemicals will spread to new regions of the world formerly free of intensive chemical use in agriculture.
- Applications, such as engineering Bt. toxin in plants, can actually lead to increased pesticide use through build up of Bt. resistance and the destruction of ecological alternatives for pest control.
- The engineering of a toxin into the plant itself might increase toxins in the plant and in the ecosystem.

Roundup is a broad spectrum herbicide that kills everything green. In the words of Monsanto's President,

"Many of you have heard of Monsanto's Roundup herbicide.

It's non-persistent...biodegrading within a few weeks after application. It doesn't leach into groundwater. It's essentially non-toxic to human and other animals. And it's very effective at killing weeds — so effective, in fact, that Roundup would control soybeans as well as weeds if it should come into contact with both.

At least, that was the case until Monsanto developed Roundup Ready soybeans. Roundup Ready soybeans express a novel protein which allows them to thrive, even when sprayed with enough Roundup to control competing weed. With the spread of Roundup through genetically engineered crops, Monsanto has requested for and received permission for a three fold increase in herbicide residues on genetically engineered soya beans. They can now sell soya beans contaminated with 20 parts per million compared to the earlier unit of 6 parts per million".

Glyphosate, the principal constituent of Roundup can kill fish in concentrations of 10 parts per million. It kills earthworms, it is also toxic to many soil microorganisms which are essential for plant growth.

The use of Roundup Resistant crops is forcing others to shift to genetically engineered crops because of pesticide drift. As Dr. Ford Baldwin, a weed scientists from the University of Kansas has reported, 'Pesticide drift caused crop destruction increases the pressure for non-users...to get on the Roundup Ready band wagon. A neighbouring farmer not using the technology stands to have his fields destroyed of the Roundup herbicide drifts onto his fields'.

Roundup Ready Soya (RRS) is the most widespread genetically engineered crop introduced so far. RRS is basically one of the strategies used to push sales of Monsanto's herbicide through its life-sciences division, which, as a PR exercise, is separated from the chemical division, but which is still involved in selling chemicals. Roundup accounts for 95 per cent of all sales of glyphosate, the world's best selling total herbicide, and in 1994 represented about 60 per cent of global non-selective herbicide sales. It is Monsanto's biggest selling produce, and accounts for 17 per cent of total annual sales.

The second strategy to increase sales of Roundup is to spread the herbicide to countries where it has not been used before. In an advertising campaign in Europe in 1998, Monsanto claimed that its genetically engineered crops reduce pesticide use, and provide a safe and sustainable method of weed control. One of the ads stated: "More biotechnology plants means less industrial ones." However, while Monsanto was selling Roundup Ready crops, it was also setting up new Roundup factories around the world. Monsanto has greatly increased its manufacturing capacity of glyphosate, investing US $200 million in production and formulation technology in Australia, Brazil, Belgium, India and China.

Herbicide resistant crops are designed to be resistant to the proprietary herbicides of the company, which makes money selling both seeds and chemicals. Monsanto requires farmers buying its Roundup resistant crops to sign a contract stating that they will not buy chemicals from any other company and will not save seed. Monsanto has thus retained its monopoly through genetic engineering at a time (in the year 2000) when its patent for Roundup was expiring.

In biodiversity-rich regions, the spread of herbicide-resistant seeds will introduce toxic-chemicals. These will destroy species as well as the livelihoods of the poorest, especially in those regions of the world where farms are small, labour is abundant, polycultures control weeds and women use the weeds for food and fodder - weeds form part of the rich biodiversity of small farms, and are a useful resource. Farming systems in the Third World depend on 100-200 plant species. Monsanto's Roundup advertisements in remote villages of India state, "Are your hands tied up by weeds? Roundup will set you free." Yet on of the main purposes of Roundup Ready crops is to increase the use of Roundup herbicide. The claim that Roundup products are safe is a contradiction in terms because a chemical used for its toxic effects on plants cannot be environmentally benign. There is evidence that Roundup can cause harm to the environment and human health even at current levels of use. A new study indicates that glyphosate can be readily released from soil particles, and therefore may leach into water.

- The Northwest Coalition for Alternatives to Pesticides found that products containing glyphosate are acutely toxic to humans. Symptoms include eye and skin irritation, cardiac depression and vomiting (CO_x, Glyphosate, *Journal of Pesticide Reform,* Fall 1995).
- A report for the Environmental Health Policy Program at the University of California at Berkeley, found that glyphosate was the third most commonly cited cause of pesticide-related illness in agricultural workers.
- The US Fish and Wildlife Service has identified 74 endangered plant species threatened by the use of glyphosate.
- In October 1999, environmental campaigners demanded a Europe-wide ban on Roundup after a EU report was leaked which warned that Roundup could kill insects and spiders vital to agricultural ecosystems (Baldwin, *Guardian,* 13 Oct. 1999).
- Greenpeace and other NGOs have revealed that soya plants sprayed with Roundup contain more plant oestrogens and so are possibly hormone-or endocrine-system disrupters.
- Dairy cows eating RRS are producing milk with different chemical characteristics (higher fat levels) than cows eating regular soya beans.
- A study published in the journal *Cancer* revealed links between glyphosate and non-Hodgkin's lymphoma (a cancer of the lymphatic system).
- Monsanto's ecological risk-assessment for RRS assesses risks only in the US and European context, although RRS is likely

to be grown and/or exported to environments of higher ecological risk.
- Irish authorities made public U.S. EPA documents that revealed that Monsanto's Roundup-resistant sugar beets were dying in alarming numbers after having been sprayed with Roundup.

The use of this toxic-to-plants, non-discriminating herbicide threatens to lead to large-scale elimination of indigenous species and cultivated varieties, damaging soil fertility and human health. The claim that soil conservation would be promoted, is based on comparing a large monoculture farm using other herbicides, and a similar farm using Roundup. However, the expansion of Roundup Ready crops will be introduced in to the biodiversity-rich agro-ecosystems of the Third World. The direct destruction of biodiversity will, in fact, lead to more rapid soil and water erosion, since without cover crops, there will be no protection against the tropical sun and rain. Roundup Ready crops will lead to increased use of Roundup and hence destruction of both cultivated and wild biodiversity. Findings such as these throw into question Monsanto's unsupported assertion of Roundup as an environmentally acceptable herbicide.

The genetic engineering option is compared to chemically intensive, large scale industrial monocultures instead of to ecological organic agriculture, which is the real alternative. Thus, in the case of Bt. potato, it is stated that genetic engineering leads to saving of US$ 6 per acre (per 0.4 hectares) based on insecticide-control costs of $ 30 to $120 per acre. However, when compared ecological agriculture, Bt. potato increases the costs by $25 to $115 per acre and correspondingly, also *increases insecticide* use. The industry's assessments give a benefit without calculating the additional costs of seeds and royalties as well as the agrichemical use which is a necessary part of Bt. resistance management.

Herbicides and pesticides are toxic chemicals aimed at controlling weed and pest problems in crops. However, these reductionist 'solutions' of the Green Revolution have proved non-sustainable. Herbicide residues in soils have led to decline in yields, and pesticide use has led to an increase in pests both through the killing of the pests' predators and the emergence of pesticide-resistance in pests.

Genetic engineering is now deepening the reductionist paradigm of controlling pests through the creation of herbicide-resistant and pest-resistant crops. These applications account for more than 80 per cent of the biotechnology research in agriculture. Their introduction will also lead to increased chemical use if 'superweeds' and 'superpests' are created as a result of biological pollution.

The Myth of Safety

Experience has taught us a few simple lessons over the centuries:

- That each time we manipulate nature technologically, there is an ecological impact, whether large or small.
- That the negative impact generated should be internalized in the costs of production. This is the Polluter-Pays Principle.
- That if there is scientific uncertainty about the impact, we should err on the side of caution. This is the Precautionary Principle.

Good science is aware of ecological impact of new technologies, internalizes the costs of the technologies, and acts cautiously on issues of uncertainty. Bad science is blind to and ignorant about ecology, the Precautionary Principle and the Polluter-Pays Principle. All technologies generate social and environmental costs. However, the costs generated by genetic engineering are different in nature and scale because life forms reproduce and multiply - and disasters unlashed through genetic engineering cannot be halted. Further, since genetic manipulations play with the very fabric of life, the potential of ecological instability is very high.

The potential impact of genetic engineering includes:

- The impact on the organism itself.
- The impact on the ecosystem in which the GMO is released.
- The impact on human society.
- The impact on human health.

Scientifically informed decision making would be based on knowledge of how to create GMOs and to apply biotechnology to agriculture and medicine, matched with knowledge of the social-ecological impact. However, not only are the ecological risks not being investigated, the knowledge of risks is being suppressed and censored. The right to knowledge and the right to information is a basic right of citizens in democratic society. The right to be free from environmental risk is also a fundamental human right. The human right to environmental safety in the special context of biosafety is, however, being systematically violated by the biotech industry and by governments promoting the interest of industry by sacrificing the obligation to protect the public interest and the environment.

Genetically engineered crops and foods are being launched in a context in which profits are privatized through IPRs. The public is kept deliberately ignorant of the true social costs through the denial of the need for biosafety regulations and the consumers 'right to know' through the labelling of genetically engineered foods.

Genetically modified foods threaten public health, and have earned themselves the popular label of Frankenstein foods because they contain genes from unrelated organisms - from animals, bacteria and viruses. The anxiety about the impact on health and the ecology of these novel foods is partly founded on the experience of such epidemics as BSE (known as Mad

Cow Diseae). It is also founded on the basic scientific fact that introducing novel genes into crops will change their physiology and biochemistry, and this could have harmful effects on health.

L-tryptophan is a food supplement, and millions of people in North America have been using it regularly since the 1980s. One producer, Shawo Denko, used genetic engineering to produce L-tryptophan. In late 1989, thousands of North Americans fell ill. Within months dozens had died and thousands were maimed as a result of EMA (eosinophilia-myalgia syndrome). L.R.B. Mann and D. Straton have called the tryptophan disaster 'The Thalidomide of Genetic Engineering'. (*Third World Network Features,* News Release, 1999).

If a purported single chemical - the natural animo acid tryptophan, better than 98.5 per cent pure and definitely meeting the notorious 'substantial equivalence' test - can turn out, when genetically engineered, to kill dozens and cripple thousands, what will it take to check properly a potato containing a synthetic 'exact' copy of a gene for a toxin from the African clawed toad? Reference to toads is not a fairy tale in the genetic engineering world. Biotech companies are engineering toxins from the wasps, the cone snail, from the deadly scorpion or the Australian funnel web spider into plants so that plants produce their own poisons. This is supposed to be a solution for pest control, but will render the GM plant toxic, killing not just pests but also beneficial insects. Nothing is known of how safe it is for humans to eat foods containing genes from scorpions, wasps, spiders and snails. (Action Aid, *Astra Zeneca and its Genetic Research,* 1999)

Genetically engineered foods have been cleared by agencies on grounds that they are substantially equivalent to their naturally occurring counterparts. Yet, the method of production clearly changes the effect of foods. When yeast was genetically modified to obtain increased fermentation, it was unexpectedly discovered that the metabolite metyl-glyoxal accumulated in toxic and mutagenic concentrations (Inose and Murata, *International Journal of Food Science Technology,* 1995).

Monsanto's transgenic soya was approved for sale in the UK from 1996 by the UK Novel Foods committee as 'substantially equivalent' and therefore safe. However, it was found to have a 26.7 per cent increase in a major allergen, trypsin inhibitor, which is also a growth inhibitor. In an article in the *Journal of Nutrition,* 1996, B.G. Hammand and others reported that when rats were fed the transgenic soya, their growth rate was inhibited.

Dr. Arpad Pusztai's research, which created a major controversy in the scientific community, showed that potatoes genetically engineered with snowdrop lectin seemed to suppress the immune responses of young rats and harm the development of vital organs. Dr. Pusztai was retired from the Rowett Research Institute in Aberdeen as a result of this work. But Dr. S.W.B. Ewen, a senior pathologist at the University of Aberdeen confirmed Dr. Pusztai's results through independent experiments, and many scientists rallied to his support. The medical journal *The Lancet* published his study in spite of pressure being brought on the editor. A ban was imposed on growing genetically engineered crops of any kind in the UK for three years. UK laws now require mandatory labelling of all genetically engineered foods.

The consumers' freedom to eat GE-free food is also threatened by the inadvertent contamination of seed, as was the case in Europe in the spring of 2000 when it was found that conventional seed bought from Canadian suppliers included GE varieties.

In genetic engineering, genes are transferred from one organism to the other. This gene transfer can result in the production of new proteins. Food that was safe could therefore become dangerous. Pioneer HiBreed engineered soya with a gene from the brazil nut to improve the protein content. Researchers at the University of Nebraska tested these soya beans on samples of blood serum taken from people allergic to brazil nuts. The tests revealed that if these people had eaten the soya bean, they would have suffered an allergic reaction that could have been fatal. As Marion Nestle stated in the *New England Journal of Medicine,* 1996: 'In the special case of transgenic (GE) soya beans, the donor species was known to be allergenic, serum samples from persons allergic to the donor species were available for testing and the product was withdrawn. The next case could be less ideal and the public less fortunate.'

For a long time, Monsanto claimed that its recombinant bovine growth hormone (rbgh) was safe. Recent research has shown that milk from cows treated with (rbgh) may contribute to enhanced risk of mammary cancer by increasing the concentration of IGF-$_{I}$ (insulin-like growth factor) in milk (Outwater, et.al., *Medical Hypothesis,* 1997); Gebaner, *Anti-cancer Research,* 1998; Hawkinson, et.al. *Lancet,* 1998).

Genetically engineered foods can also be hazardous because the vectors used to construct transgenes can infect mammalian cells and resist breakdown in the gut. In a study designed to test the survival of viral DNA in the gut, mice were fed DNA, and large fragments were found to survive the passage through the gut and enter the blood-stream (Schubbert, et.al., *Molecular Genetics*). Invasive strains of *Shigella* and *E.coli* can be similarly absorbed. The crossing of species barriers to make transgenic crops and foods also facilitates the crossing of disease barriers across species. As biologist Mae-Wan Ho says:

"Natural genetic parasites, like viruses and other transposable elements, proteins and plasmids, are naturally specific to certain species. They have species barriers, genetic barriers. A virus from a pig will not generally attack humans, and so on. What genetic engineering does is to destroy these species barriers. So when you join these viruses and transposable elements from widely different sources, you create similarities to all these different species. You are levelling the gene-transfer barriers that naturally exist. I really am worried about this because since 1993 an increasing number of publications have reported that horizontal gene transfer is responsible for new and bold pathogens arising" (Quoted in Suzuki, *From Naked Ape to Super Species*).

In a study carried out in Eastern Germany, streptothricin was administered to pigs from 1982. By 1983, plasmid encoding streptothricin-resistance was found in the pig gut-bacteria. By 1984 this had spread to the gut-bacteria of farm workers and their families, and the following year to the general public and pathological streams of bacteria. The antibiotic was withdrawn in 1990, but the prevalence of the resistant plasmid remained high when monitored in 1993 (Tschape, *FEMS Microbiology Ecology,* 1994).

In 1995, Stephenson and Warnes cautioned, "The threat of horizontal gene-transfer from recombinant organisms to indigenous ones is very real, and mechanisms exist whereby, at least theoretically, any genetically engineered trait can be transferred to any prokaryotic organism and many eukaryotic ones" (*Biotech,* 1995).

In 1996, the Advisory Committee on Novel Foods and Processes advised the UK Government to vote against an authorization sought by Novartis for a genetically engineered maize containing an ampicillin-resistant gene. They felt that the presence of this intact marker gene, together with a bacterial promoter gene posed an unacceptable risk (*Ag. Biotech News and Information*). A report in the *New Scientist* of 30 January 1999 confirmed that antibiotic resistance could jump from genetically modified foods to bacteria in the gut.

Dr. Mae-Wan-Ho in *Genetic Engineering: Dream or Nightmare?* (1997) has identified the following risk to human health from genetically engineered foods:

- Toxic or allergenic effects due to transgenic products or interactions of transgene with host genes.

- Vector-mediated spread of antibiotic resistance market genes to gut bacteria and to pathogens.
- Vector-mediated spread of virulence among pathogens across species by horizontal gene-transfer and recombination.
- Potential for vector-mediated horizonal gene transfer and recombination to create new pathogenic bacteria and viruses.
- Potential of vector-mediated infected cells after ingestion of transgenic foods, to regenerate disease viruses, or for the vector to insert itself into the cell's genome causing harmful or lethal effects including cancer.

Because of the health and environmental risks of so-called Frankenstein Foods, consumers are rejecting genetically engineered foods. The 'new, improved' products, as the biotechnology industry has tried to sell them, are 'new' but not 'improved' in the consumers' view. Through consumer pressure, food retailers and food traders have started to deal in GE-free foods. In April 1999, Unilever, Nestle and Cadbury announced that they were phasing out genetically modified products globally because of customer resistance. Tesco and the Co-op did the same, joining the other big supermarket chains. In August 1999, Edeka, German's largest retailer declared that it is completely abandoning GE foods. Other large German retailers to go GE-free are Spar and Metro. In September 1999, Brake Bros, Britain's biggest distributor of frozen foods, eradicated GM ingredients from all its products, making it the first wholesale catering supplier to be totally GM free. The group promises that all 2,000 food items it supplies to restaurants, hotels, schools and hospitals will be GM-free.

In Japan, the import of GM soya beans has declined rapidly as food-processing companies shift their purchases to soya beans that have not been genetically modified. The Japanese Government has announced plans to require labelling of products made from GM crops beginning in April 2001. In August 1999, Kirin, Japan's largest brewer and a leading biotech company, announced that by 2001 it would stop using GM corn to make beer. Sapporo Breweries Ltd, Japan's third largest beer producer also announced that it will stop using GM corn to make beer. Honda Trading Co. is building a plant to bag GE-free soya beans and will contract with US farmers for their production. Fuji Oil Ltd, Japan's largest manufacturer of soya bean protein food products will stop using GM soya bean from April 2000.

When concerns were raised about GM safety, the US government and the biotechnology industry insisted that segregation and labelling of GM foods were not technically possible. Consumer boycotts, however, have made segregation a possibility. In March 1999, two major grain processors, ADM and A.E. Staley Mfg. Co., announced that they would not accept any varieties not approved for import into Europe. ADM started to procure non-GM soya at a premium.

As reported in *Business Week* of 18 October 1999, Dave Borttger a US farmer, like many others in his country, is having to pay for having cultivated GE crops. ADM is offering 8 cents a bushel more for the old-fashioned corn that Borttger grows on half of his land than the gene-spliced corn he grows on the other half. But if testing reveals even a tiny amount of altered gene in the GM-free grain, Borttger will have to pay ADM for the cost of dumping the entire load.

The concerns for safety are leading to a shift in trends. Instead of millions of acres being converted from non-GM to GM crops, the reverse has started to happen.

In the USA the American Corn Growers Association, in an official press release dated 25 August 1999, has proposed that farmers explore the option of planting non-GM crops in the light of the uncertainty caused by GMOs (genetically modified organisms). The consolidated Grain and Barge Company, in a letter to producers, state that consignments containing GMO contamination, "no matter how trivial, will not be eligible for premium prices as GMO crops become increasingly unsaleable on international markets". The Canadian Wheat Board has stated that no transgene varieties should be registered for production in Canada. In Brazil, the state of Rio Grande de Sul has declared itself GE-free. In India, hundreds of villages have taken a pledge to be GE-free zones. The people are making their choice clear. They are voting for food freedom and food democracy, food security and food safety.

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