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Biotechnology and Food

Ten Thousand Years of Sowing Seeds, One Hundred Years of Harvesting Genes

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Summary

There are two great success stories of biological technologies in the twentieth century: the taming of infectious disease by antibiotics and vaccines, and the harnessing of genetic improvement in crops, epitomized by the Green Revolution. Both have allowed the impact of devastating hardships around the world to be significantly reduced. In both cases, the very success of technology has lulled us into a false sense of security. Most people are no longer preoccupied with the danger signals of death and starvation that drove many of the original technological achievements on which these advances were based.

It is the theme of this *Backgrounder* that the argument that current food production methods are adequate, and that all that is needed to solve hunger problems is a more perfect distribution system, is a dangerously complacent one. Such policies will fail to ensure that adequate cheap supplies of food are generally available—especially given an expected world population increase of some 3 billion people by 2050.

Four main aspects of this topic will be explored in this paper. First, the driving forces behind innovative crop gene modification will be presented—that is, why this research is taking place. Second, the paper will explain the role already played by gene technology in crop improvement, and will point out why better methods are needed. Third, some of the specific details of the new gene technology and some explanation of how it is used by breeders will be given, and finally there is a discussion of the risks posed by innovation in crop breeding using gene manipulation.

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HOW GENETICS IS USED TO IMPROVE AGRICULTURE

Genetically modified crops (GM crops, GM foods) represent the most obvious outcome of recent technological innovation in plant breeding, and they represent one way in which advances in breeding techniques and basic science have yielded better and quicker ways to create improved crops. These are outlined in Table 1.

Many different approaches to targeting desirable traits are being explored. They all offer a common, very decisive, advantage over older methods—they enable the breeder to avoid introducing the many thousands of other often undesirable genes that are present in the donor organism.

A first step in breeding new crop hybrids is identification of the trait that needs to be improved—for instance, resistance to a fungal disease in a cereal crop. A search is then usually made for new breeding stock that displays intrinsic resistance to the particular fungus, virus or bacterium causing disease, and frequently it is found that plants consist of several or even many 'races' which display different attributes with regard to disease resistance. Very often it has been necessary to test wild relatives of the domesticated crop variety as a possible source of new genes, or even wild plants from other, more distant biological groups to find novel intrinsic resistance mechanisms to particular diseases. The practical details of breeding traits from such diverse biological sources into domesticated food crops are a major experimental hurdle because crosses involving different plant species are often infertile, and potentially valuable hybrid embryos need to be rescued using special laboratory and greenhouse techniques.

If the parental stocks used in a plant-breeding programme are from the same species, cross-pollination to produce improved hybrids is much more straightforward. But there is another problem to consider. Existing domesticated crops called Elite varieties have undergone extensive breeding to ensure that they are high yielding or have other desired traits to assist farming, such as suitability to local climates and soils. Natural cross-pollination introduces thousands of new traits into the hybrid and many of them are undesirable and destroy the hard-

Table 1: Old and New Ways of Breeding Crops

Stage	Twentieth-Century Methods	Twenty-First-Century Methods
Finding desirable traits	Searching among closely related species Nature of trait poorly understood	Searching among wider range of species, completely detailed genetic maps, searching gene databases, numerous alternatives for scientifically based trait manipulation
Breeding with different parent to generate potentially useful hybrids	Desired gene contaminated with thousands of undesirable genes Cross-pollination, interspecies and intergenus crosses rescued by laborious laboratory procedures (embryo rescue)	Genetic dissection to select only the desired genetic material, novel tools (gene ferries or vectors) and methods for gene injection to enable single traits to be transferred into new hosts. New tools (for example, detailed genetic maps, genetic markers) to speed up breeding of less well-understood traits
Mating of novel hybrids with Elite varieties	Extremely time-consuming major hurdle for crop breeding	Gene cloning and marker technologies reduce this hurdle by minimizing introduction of unwanted genes and reducing time and labour needed to regain Elite status. (Breeding is still needed to adapt hybrids to local conditions.)

gained advantages of the Elite varieties. Time and effort have to be spent in conventional breeding programmes to remove these undesired genes and it may take 5–10 years for a new crop to reach the market.

Advances in DNA science have created new methods and concepts that allow conventional breeding to be done more speedily and efficiently.

The Driving Force for Genetic Modification

Some major practical results of using gene technology in agriculture are given in Table 2 and they provide insight into the reasons why genetic modification is being used so enthusiastically by modern plant scientists. The different aspects of crop improvement are listed in the table in the approximate order in which they are reaching the consumer marketplace.

These practical outcomes are best illustrated by the story of GM crops in the US and they also indicate the likely directions to be taken by agriculture in Australia in the near future.[1] It should be added that GM crops are grown extensively outside the US, in China for example.

The main GM crops in the US are currently herbicide-tolerant soybeans, insect-resistant (Bt) cotton, and insect-resistant corn. US adoption of these new crops underwent very significant changes from 1995 through to 1998. First introduced in 1996, 40 per cent of all soybean acreage was planted with herbicide-resistant GM varieties by 1998. Nineteen per cent of corn acreage was planted with European corn borer-resistant GM varieties in 1998, and the acreage of cotton devoted to GM herbicide-resistant varieties was 26 per cent by 1998. In 1997, adoption of herbicide-tolerant varieties led to statistically significant reductions in herbicide use in 4 out of 8 regions across all crops, mostly for soybeans. These figures are supported by the assessments of Australian weed scientists.[2]

MANY DIFFERENT APPROACHES TO TARGETING DESIRABLE TRAITS ARE BEING EXPLORED. THEY ALL OFFER A COMMON, VERY DECISIVE, ADVANTAGE OVER OLDER METHODS

Bt insecticide is a natural protein insecticide produced by bacteria. Bt-insecticide-based GM technology was widely deployed in the US in

Table 2: Improvement to Crops from Modern Genetic Technologies

Type of Improvement	Examples
Lower cost, more efficient production	Herbicide-tolerant plants
Environmental benefits such as smaller farm area, lower amounts of persistent chemical pesticides, substitution with more desirable pesticides	Herbicide-tolerant plants, Bt-maize
Better, faster breeding methods	Marker technologies, genome science, gene-transfer vectors, biolistics
Disease resistance, pest resistance	Bt-maize, natural plant disease prevention genes (R-genes), novel anti-fungal infection defences, virus resistance
Improved nutrition	Vitamin A-containing rice, iron-enriched rice
New crops, new products	Novel oilseeds, novel plastics
Improved yields	Probable medium-term outcome of basic plant science as exemplified by boosted rice output with maize genes

the 1997 season. Decreased use of chemical pesticides targeted at the insects against which the Bt gene protects plants was also observed by the USDA Economic Research Service in overall US statistical data. Encouragingly, in 4 out of 7 regions, adopters of Bt cotton appeared to obtain significantly higher crop yields than non-adopters, and similar results were observed for Bt corn.[3]

In 1999 in the US, it was expected that 40 per cent of the corn, 50 per cent of the cotton, and 45 per cent of the soybean acres would be planted with genetically modified crops, reducing the use of chemical pesticides by millions of kilograms.[4] A further benefit of GM herbicide-resistant crops is that they create more scope for minimum tillage farming, which reduces erosion of topsoil.

Most GM foods currently available to consumers are modified so that the benefits are largely realized as decreased cost of production rather than improvements in product quality. Thus, the main economic outcomes from GM technology in the short term should be marginally lower food prices and better economic competitiveness and financial vitality in farming regions. This should be realized especially in low-cost agricultural countries such as Australia, the US and Canada.

A staggering number of children in the world—200 million—are malnourished. 'Golden rice' vividly illustrates how GM foods can greatly benefit these children, and consumers generally, by providing food with greatly improved nutritional qualities.[5] Newly developed strains of rice have been created by a team led by Dr Ingo Potrykus in Switzerland to meet the needs of people suffering from vitamin A deficiency, the world's leading cause of blindness, affecting as many as 400 million people.

IN 1997, ADOPTION OF HERBICIDE-TOLERANT VARIETIES LED TO STATISTICALLY SIGNIFICANT REDUCTIONS IN HERBICIDE USE IN 4 OUT OF 8 REGIONS ACROSS ALL CROPS, MOSTLY FOR SOYBEANS

Dr Potrykus' team has also created rice which has high levels of iron. Iron-deficiency anaemia is the most common consequence of malnutrition,[6] and it afflicts some 3.7 billion people. Recently, the long-touted potential for food crop yields to be increased by GM technology has been unexpectedly confirmed by an announcement that rice yields can be boosted dramatically—by about 35 per cent—by introducing maize genes to confer on rice more efficient photosynthesis. The huge excitement generated by this early report will be amply justified if these laboratory and greenhouse findings can be even partly confirmed in practical agriculture.[7]

A STAGGERING NUMBER OF CHILDREN IN THE WORLD—200 MILLION—ARE MALNOURISHED. "GOLDEN RICE" VIVIDLY ILLUSTRATES HOW GM FOODS CAN GREATLY BENEFIT THESE CHILDREN

The Origins of Genetics and First Applications to Plant Breeding

In the twenty-first century, genetic modification is routinely carried out by modifying the genes within cells in a deliberate and direct way. The outcome of experiments can be planned beforehand and new hybrids created by design, often with the aid of a computer and chemical synthesis of artificial DNA. This revolutionary technology had rather modest beginnings. They date back long before the science of genetics was conceived.

Jared Diamond's prize-winning book *Guns, Germs, and Steel: A Short History of Everybody for the Last 13,000 Years*, contains a fascinating discussion of how agriculture began near what is now Syria some 9000 years ago.[8] Both inbreeding, or self-pollination, and cross-breeding, or interspecies hybrid formation, played an important role in the origins of our staple foods. Crosses between different species of flowering plants are, in fact, a common mechanism by which new species of plant originate. Bread wheat, for example, contains virtually the complete chromosomal sets from three distinct grasses whose relatives grow wild today in the Middle East.

Wild grasses near the Fertile Crescent contained a high percentage of hermaphrodite 'selfers'. These are plants that normally self-pollinate but which occasionally cross-pollinate. Such 'selfing' characteristics were exploited by the earliest farmers. Occasional variants (mutants) produced seeds with a favourable characteristic that made them more useful as foods. These variants were automatically favoured by farmers for use in the next season's crops as 'selfing' would give crops in the next season similar characteristics.

In the main cereal crops, ability to cross-pollinate is not confined to individuals of the same species but can occur between species. Bread wheat, as mentioned before, is one such inter-species hybrid. It was originally generated in the Fertile Crescent thousands of years ago, and it is now the most valuable crop globally. Thus, both natural evolution and conventional plant breeding can generate massive numbers of cross-species, gene transfer events.

BREAD WHEAT, AS MENTIONED BEFORE, IS ONE SUCH INTER-SPECIES HYBRID. IT WAS ORIGINALLY GENERATED IN THE FERTILE CRESCENT THOUSANDS OF YEARS AGO, AND IT IS NOW THE MOST VALUABLE CROP GLOBALLY

In short, several thousands of years of mostly unintentional, non-scientific selection of plant varieties for advantageous characteristics have led to modern varieties of cereals and other crops.

Genetics as a Science

The concept of a gene as a particle of inheritance was formulated by Gregor Mendel in the 1860s. This concept was later extended greatly, so that we now know that the particles postulated by Mendel and others at the turn of the twentieth century are DNA molecules, and that genes are physically carried in the nucleus of cells. All of these discoveries greatly influenced and stimulated plant breeding and crop improvement, and have had a major influence on global agricultural productivity since the early years of the twentieth century.[9]

These breeding developments rely heavily on natural genetic diversity ('germ plasm') present in wild plant varieties, and by 1900 the first germ plasm collections were established. A solid empirical and experimental basis for the science of genetics was put in place between 1900 and 1930. An example of the impact of this science of 'Mendelian genetics' was the discovery of hybrid vigour, which explained the better performance of intraspecies hybrids. Between 1940 and 1980 in the United States, per hectare yields of maize tripled and those of wheat and soybeans doubled. Much of this increase was achieved through scientific breeding programmes.[10]

Deliberate cross-species gene transfer by pollination from related species of wild grasses into wheat actually began in 1930. The driving force for these experiments is the damaging susceptibility of wheat to serious, widely occurring fungal diseases known as rusts and smuts. McFadden showed in 1930 that the wild grass genes from emmer (*Triticale tauschii*) could be bred artificially into bread wheat (*T. aestivum*) to create the new variety 'Hope', which was responsible for one of the longest rust-free periods in the history of US wheat cultivation.

DNA Manipulation

Modern genetics involves much manipulation of DNA outside of cells as a technique to find out how living organisms work and to achieve practical outcomes like modifying crop plants. Three seemingly simple ideas form the basis of these procedures. They seem very simple but they required great brilliance, luck and hard work by many scientists to establish that they are indeed true. These ideas are:

1. That fundamental genetic components of cells are chemical polymers that can be extracted from cells, chemically purified, analysed, and put back inside living cells to redirect their activities (discovered by Oswald Avery in 1944).
2. That the genetic material acts as precisely-stored, coded information used by cells to

direct their activities (discovered by James Watson, Francis Crick and many other workers around the years 1952–1960).

3. That the genetic material can be deliberately rearranged relatively easily outside cells, in the test tube, by using certain enzymes extracted from cells, and that the rearranged information can be used by cells (discovered by Stan Cohen, Paul Berg and other workers around 1972).

These three concepts, discovered largely through academic research on bacteria, form the basis of our current ability to change genes inside cells deliberately. In a very real sense, much of the genetics that hits the headlines in newspapers today is a rerun of the bacterial genetics of the 1970s, albeit in much more complex organisms, using far more powerful procedures and on a much more economically ambitious scale.

The Red Queen

> 'Well in *our* country', said Alice, still panting a little 'you'd generally get to somewhere else—if you ran very fast for a long time, as we've been doing.'
>
> 'A slow sort of country!' said the Queen. 'Now *here*, you see, it takes all the running *you* can do, to keep in the same place. If you want to get to somewhere else, you must run at least twice as fast as that!'
>
> [Lewis Carroll, *Through the Looking Glass*]

The advances obtained from conventional breeding exemplified by hybrid maize and other high-performing cereal crops are not without their problems, since over-reliance on particular Elite inbred varieties ('monocultures') can lead to spectacular crop failures due to unrestricted spread of diseases such as smuts and rusts of cereals. One approach (already mentioned) which has been enormously important in managing these disease problems is to cross-breed Elite lines with diverse wild grasses, which contain novel genes for disease resistance. The aim of such experiments is to combine new useful genes from the wild parent with the many agronomically important genes from the Elite parent. These breeding efforts have been enormously important in giving global food security, since about the mid-1930s, when disease problems of monocultures first emerged and, as already stated, the world currently has adequate food supplies because of them.

REGRETTABLY, MANY DISCUSSIONS OF THE HAZARDS POSED BY GM FOODS DO NOT APPEAR TO INVOLVE RIGOROUS SCIENTIFIC INPUT

But, unfortunately, parasites evolve too, and new forms of crop diseases constantly emerge to cause problems with existing disease-resistant varieties. Thus, crop breeder and pathogen are part of an ongoing race, in which the breeder, as the Red Queen suggested to Alice, if he or she wants to get somewhere 'must run at least twice as fast as that!'.

Risks, Hazards and Other Objections to GM Foods

Many questions are raised about the risks posed by the artificial transfer of new genes into food crops. Major areas of debate centre on whether novel GM crops create significant environmental hazards or whether transfer of pollen from GM crops into biologically related natural species such as weeds will have detrimental effects. Perhaps most importantly, consumers will seek assurances that there are no unexpected hazards associated with eating these products.

'THERE IS AS YET NO SUBSTANTIAL EVIDENCE THAT GM FOODS ARE INHERENTLY MORE DANGEROUS THAN CONVENTIONAL FOODS'

Regrettably many discussions of the hazards posed by GM foods do not appear to involve rigorous scientific input. A welcome exception to this is the series of papers in the 22 April 1999 issue of the science journal *Nature*.[11]

The editorial to that issue of *Nature* summarizes the problems with this debate succinctly:

> Two points about the scientific debate must be made immediately. The first is that much of the recent outcry about the potential dangers of such foods, particularly in Britain, has been based on exaggerated claims … There is as yet no substantial evidence that GM foods are inherently more dangerous than conventional foods.
>
> The second point, however, is that … many scientists feel that the widely quoted 'hazards' such as the potential spread of herbicide-resistant 'superweeds', have been overemphasized by the critics.[12]

Genes Move Naturally between Species as Well as between Generations—but Many People Still Don't Realize it

Moral objections, or even objections that are a tricky mixture of moral conviction and science, are often raised against GM food. The supposed 'unnatural' transfer of genes between species is a major source of objection, and it is implied that this breaks some natural law, or is at least a radically new precedent previously not part of our food supply.

For example, it is boldly stated at the start of the Australian Conservation Foundation's June 1999 *Habitat Australia* supplement 'Say No! to Gene Tech's Bitter Harvest' that:

> Genetic engineering enables the tree of life to be scrambled for the first time. It allows genes to be transferred across species boundaries, from any living organism to any other—animals to humans, humans to bacteria, microbes to plants, and so on. This could never happen in nature or through traditional breeding, where sows deliver piglets and roses make rosebuds.

This statement is totally false. There is, in fact, no overarching natural law or scientifically established biological function associated with containment of genes within species. Those barriers that do exist may largely be just accidents of evolution, and there is definitely no absolute genetic barrier between species. Recently, much new evidence for gene movement has emerged from complete analysis of the total encoded DNA message of many organisms—the so-called 'Genome Projects'. These studies have made biologists realize, with surprise, that transfer of genes between distant branches of the tree of life is the norm, not the rare exception.[13]

THERE IS, IN FACT, NO OVERARCHING NATURAL LAW OR SCIENTIFICALLY ESTABLISHED BIOLOGICAL FUNCTION ASSOCIATED WITH CONTAINMENT OF GENES WITHIN SPECIES. THOSE BARRIERS THAT DO EXIST MAY LARGELY BE JUST ACCIDENTS OF EVOLUTION, AND THERE IS DEFINITELY NO ABSOLUTE GENETIC BARRIER BETWEEN SPECIES

One of the sources of the serious misconceptions about nature exemplified by the ACF statement is that the 'reproductive isolation' or species concept taught in school biology is merely a conceptual model (and a simplistic model at that) which is used to improve understanding of how creatures evolve in natural populations. It is not a prescription for what *ought to be*. For many organisms, their behaviour in nature does not conform to any rule that species must be reproductively isolated from one another—this is especially true for flowering plants, which very often form hybrids or new species as a result of natural cross-pollination between species.

Such interspecies cross-pollination, carried out artificially using conventional technology, has in the past yielded several new foods, for example, nectarines and boysenberries, and has been used extensively by plant breeders to improve a wide range of food crops. These include potatoes and tomatoes, in addition to the cereal hybrids already mentioned.

Genes Move around within a Species Too!

Nobel prize winner Barbara McClintock is famous for initiating a new era in genetics, which flourished from the mid-1970s onward.

McClintock's work made biologists realize that there is much random gene movement going on within cells. This natural DNA rearrangement plays a very significant role in natural evolution of all plants and animals. For example about 37 per cent of human DNA consists of this genetically mobile category of DNA.[14] The natural mobility of this DNA is very similar in many aspects to DNA rearrangements exploited by genetic scientists in the laboratory. Extensive scientific knowledge about natural DNA rearrangements is the basis for the carefully considered scientific conclusion that the risks posed by GM foods are similar to those displayed by conventional crops.

Religious Objections and Genetics

Moral judgements of value and codes of behaviour concerning dietary laws handed down by religious tradition rest on a different set of assumptions and rules of behaviour. But these customs are obviously very important influences affecting the acceptance of some foods, and one of the unsettling aspects about new GM foods is that they require rethinking of the reasoning behind judgements which involve religious dietary rules.

Consider the question 'If I introduce a pig gene into chickens, and eat the meat of the modified chickens, am I eating pork?', which represents a common concern of this type. Genetic knowledge can help refine the question by telling us that it is not the mere fact that the gene comes from a pig that makes it necessarily distinctive, because when one focuses on individual genes, a substantial part of the DNA from a pig is essentially the same as that of the chicken, and perhaps the objection to pork is better related to the behavioural habits of the pig and its susceptibility to parasites, which are not determined by a single gene.

Regulation and Risks

One can approach the issue of whether GM crops are adequately regulated by comparing the way in which conventional and GM crops with similar characteristics are assessed. Consider, for example, herbicide-resistant crops. By applying conventional breeding methods, plant breeders have developed varieties of fodder clover and oilseed rape (Canola) that are resistant to synthetic herbicides. As these varieties are considered to be 'natural', relatively little attention has been given to their possible adverse environmental effects. They are exempt from the regulatory restrictions that apply to GM crops simply because laboratory manipulation of DNA outside of cells was not involved in their creation. Relatively little discussion is made of the movement of pollen from these 'natural' varieties into other species, as there is little perception that this constitutes a hazard.

By contrast, herbicide-tolerant plants generated by DNA manipulation, such as glyphosate-tolerant cotton (including Roundup Ready crops) or glufosinate-tolerant soybeans are subject to formal registration requirements in Australia involving the genetic regulatory body (formerly known as GMAC, currently IOGTR and soon to be OGTR), the agricultural and veterinary chemical regulator (the NRA) and other regulatory bodies. These products cannot enter the market unless vetted by committees that consider detailed submissions about their possible adverse environmental effects. If they are food-related crops, the food has to be evaluated by ANZFA—the Australia and New Zealand Food Authority—which scrutinizes health and safety implications of the genes and gene products introduced into a crop and the foods derived from them. And yet, considerably more is known about the nature of the genetic changes in the GM crop than in the natural herbicide-resistant plants.

FOOD TOXICITY PROBLEMS ARE FOUND IN BOTH GM FOODS AND CONVENTIONAL FOODS BUT THEY ARE PERCEIVED AND MANAGED VERY DIFFERENTLY, AND THE EXTRA ATTENTION GIVEN TO GM FOODS HAS WORKED IN FAVOUR OF CONSUMERS

It is sometimes argued that the technology for insertion of a foreign gene is uncontrolled because the foreign gene cassette is inserted at a randomly located chromosome location. But random insertion of naturally mobile DNA cassettes often occurs in natural varieties of plants, so no intrinsically novel risk is involved.

A similar comparison can be made between the food risks posed by GM foods and those posed by conventional plant varieties. Food toxicity problems are found in both GM foods and conventional foods but they are perceived and managed very differently, and the extra attention given to GM foods has worked in favour of consumers.

This different management is illustrated by a GM food problem arising from a Brazil nut protein, whose gene was inserted into soybeans by Iowa-based company Pioneer Hi-Bred in the hope that it would provide an improved nutritional profile of essential amino acids. Unfortunately, the particular protein selected was later found to cause reactions in the blood serum of people allergic to Brazil nuts and, not surprisingly, the GM soybean also provoked these adverse allergic reactions. As a result, this novel food has not entered the marketplace. It is worth noting that such screening is not possible with conventionally bred hybrids, as thousands of unidentified new protein antigens are introduced in the 'natural' hybridizing process.

On the other hand, selection and marketing of natural varieties of potato and celery, which had conventionally bred improvements to pest resistance, have in the past led to the selling of foods that were downright hazardous. Relatively little fuss was made about them and they were withdrawn from the market. 'Many of the nightmares predicted for genetically engineered crops have already happened [in non-GM crops]', comments Tony Connor of the New Zealand Institute of Crop and Food Research.'[15] Conventionally-bred potatoes and celery still appear on supermarket shelves without warning labels.

The above examples illustrate how public perceptions of risk are biased by the media's need for new stories which give undue attention to minuscule risks from pesticides and hypothetical fears of gene technology. For instance, an objective assessment of the relative risks of eating food suggests that microbial contamination is a *million* times more damaging than pesticide residues.[16] More than 20 per cent of Australians suffer from microbial food poisoning each year, yet these anti-GM food biases actually get in the way of better public health and better environmental management, if only by diverting attention and investment from sensible priorities.

More compelling reasons for requiring DNA-manipulated plants to be subject to special regulation are the need to obtain more familiarity with a new technology under large-scale actual conditions of use, and also to understand the detailed consequences of a far-reaching technology involving products that are released to multiply and evolve in the environment. The purposes of such a strategy are to ensure that any benefits it offers are not cancelled out by major unanticipated risks. An argument can be made that many adverse consequences of new technologies are not detected by small-scale experiments but only emerge from large-scale use (for example, the difficulties attributed to large-scale use of DDT).

MORE THAN 20 PER CENT OF AUSTRALIANS SUFFER FROM MICROBIAL FOOD POISONING EACH YEAR, YET THESE ANTI-GM FOOD BIASES ACTUALLY GET IN THE WAY OF BETTER PUBLIC HEALTH AND BETTER ENVIRONMENTAL MANAGEMENT, IF ONLY BY DIVERTING ATTENTION AND INVESTMENT FROM SENSIBLE PRIORITIES

From this point of view, regulatory oversight is required to provide an ordered and gradual implementation of a technology so that we can identify the problems and gain familiarity with the organisms.

One widely touted concern about GM crops is the escape of genes from them into other species via pollen. This process is not unique to GM crops, and large-scale raising of cultivated plants has always resulted in gene transfer to natural populations in those instances where there are related natural species. There are at least 16 documented cases of pollen cross-fertilization between conventional crops bearing herbicide- or pest-resistance genes and natural species.[17] This scenario is of greater concern when the relatives are weedy and, in general, it is the Brassica family, including Canola (oilseed rape), in which it is common to find widely distributed wild/weedy relatives. When the gene introduced into a plant variety offers some specific growth advantage (for example, insect resistance due to the Bt gene), such movement of pollen has potential for adverse environmental consequences.

Work by Thomas Mikkelson in Denmark has shown that in experimental field trials, herbicide-resistance gene movement can occur from oilseed rape into weedy relatives. If the same happens in farmers' fields, the benefits of this GM trait may be lost. The gene, however, may not give any advantage to the weedy relatives if they are not sprayed with herbicide, and will create a genetic burden by which the plant is disadvantaged and unable to compete successfully with wilder varieties. Several studies have suggested that with some crops (tobacco, oilseed rape, rice) the hybrids created by herbicide-gene escape are puny weeds rather than superweeds.[18]

It is pertinent, however, that different cultivated crops have varying abilities to produce pollen, and several have no known natural species in particular locations, and hence a pollen transfer scenario in these cases offers minimal risk. For example, genetically modified carnations have been developed by the Australian company Florigene, but these cannot effectively cross-pollinate, and have no relatives in Australia to which genes can escape by this route. Similarly, cotton in many regions of Australia has no native species of the genus Gossypium with which it can exchange pollen. Pineapple plants also do not cross-pollinate with other plant species found in Australia.

A RECENT STUDY CONDUCTED AT THE UNIVERSITY OF MAINE'S COOPERATIVE EXTENSION FARM HAS FOUND THAT THERE IS LITTLE CROSS-POLLINATION BETWEEN GENETICALLY ENGINEERED AND CONVENTIONAL CORN PLANTS IN THE FIELD

Transfer of pollen within the same species, from GM plants to non-GM plants, is a concern for the organic farming community who wish to certify that their produce is free from GM contamination. A recent study conducted at the University of Maine's Cooperative Extension farm has found that there is little cross-pollination between genetically engineered and conventional corn plants in the field. A *Bangor Daily News* story shows a glimpse of the future:

> The study revealed that ... in hybrid corn grown downwind from the GE plots, there was about a 1 percent cross-pollination in the first six rows within 100 feet of the GE corn. In the middle six rows, the frequency dropped to 0.1 percent, and in the last six rows, the frequency dropped to 0.03 percent. No cross-pollination was found in corn 1,000 feet away.[19]

One can only hope that similar articles in future Australian rural newspapers will provide assurance to Australian organic farmers that coexistence of GM farming and organic farms is feasible.

CONCLUSIONS

The various misconceptions about GM crops pointed out in this *Backgrounder* matter profoundly, because they are being exploited to create unnecessary barriers between food supply and demand. The argument that we now should turn away from using genetic innovation because we currently have adequate global food supplies ignores both the past and the future. It requires wilful ignorance of the fact that, in the twentieth century, better breeds of staple crops fed a greatly expanded world population. Furthermore, it fails to take into account the long leadtime in plant breeding, and that in the twenty-first century it will be too late if we delay research on a better food supply until problems emerge. For these reasons we should examine closely the argument that the risks of the new technology are so great that GM foods should be blocked. Several of the premises on which this case is made are simply untrue. Given the widespread adoption of this technology in North America and China, it is likely to continue being widely used, and the key policy issue for Australians to consider is how to obtain maximum advantage from this rapidly changing technology.

To imagine that mankind will achieve an adequate future food supply without considerable ingenuity is to misunderstand both evolution and ecology. We need to remember that we have limited resources to deal with the challenges of the future and that by wasting them we deprive other problems of solutions. Undoubtedly, much more debate will occur before it becomes clear where our concerns should be most focused and how these limited human resources can be best deployed.

ENDNOTES

1 See Economic Research Service, US Department of Agriculture (25 June 1999; 20 July; http://www.econ.ag.gov/whatsnew/issues/biotech).

2 For example, G.W. Charles, *et al.*, 'Current and future weed control practices in cotton: the potential use of transgenic cotton herbicide resistance', pages 89–100 in G.D. McLean and G. Evans (eds), *Herbicide-Resistant Crops and Pastures in Australian Farming Systems*, Bureau of Resource Sciences, Canberra, 1995.

3 It is worth noting that although laboratory experiments have been used to argue that Bt pollen might harm the rare monarch butterfly (J.E. Losey, *et al.*, *Nature*, 399, page 214, 1999; see comments by Aynsley Kellow, Letter to *The Weekend Australian*, 7–8 August 1999) these disputed studies involved allowing larvae to feed on milkweed leaves, dusted with Bt corn pollen. In the field, the behaviour of insects in making choices between different foods (see T.H. Schuler, *et al.*, 'Parasitoid behaviour and Bt Plants', *Nature*, 400, page 825, 1999) can greatly change the effect of toxins and there is evidence from field studies that the effect on these threatened species from Bt corn can be minimal.

4 R.N. Beachy, 'Facing Fear of Biotechnology', [Editorial], *Science*, 16 July 1999.

5 See '"Golden rice" dishes up a healthy diet', *The Age*, 15 January 2000; T. Gura, 'New genes boost rice nutrients', *Science*, 285, pages 994–995.

6 See J.L. Brown and E. Pollitt, 'Malnutrition, poverty and intellectual development', *Scientific American*, February 1996, page 2631.

7 Andy Coghlan, 'Filling the bowl', *New Scientist*, 1 April 2000, page 19.

8 J. Diamond, *Guns, Germs, and Steel: A Short History of Everybody for the Last 13,000 Years*, Vintage, London, 1998.

9 See R.M. Goodman, *et al.*, 'Gene transfer in crop development', *Science*, 236, pages 48–54, 1987.

10 See *Encyclopædia Britannica* article on 'Agricultural Sciences', 1997.

11 *Nature*, 398, 22 April 1999, particularly D. Butler, *et al.*, 'Long term effect of GM crops serves up food for thought', page 651.

12 *Ibid.*, page 639.

13 See 'One jump ahead: Genes may move between species as well as between generations', *The Economist*, 17 April 1993, pages 91–92; J. Rennie, 'DNA's new twists', *Scientific American*, March 1993, pages 89–96; W.F. Doolittle, 'You are what you eat: a gene transfer ratchet could account for

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14 Beautifully discussed in 'Chromosome 8' by Matt Ridley in *Genome: The Autobiography of a Species in 23 Chapters*, Fourth Estate, London, 1999.

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18 See Brookes, *op. cit*.

19 *Bangor Daily News*, Maine, USA, 8 January 2000.

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