THE SCIENCE MISSING FROM THE GM DEBATE

Why the opposition to GMO in agriculture may have a sound basis.

A Discussion paper

Dr Ulrich Loening
Centre for Human Ecology, Edinburgh

August 1999

Revision: 19 September 1999

Dr Ulrich Loening is a molecular biologist. In the Departments of Botany and then Zoology in the University of Edinburgh, he developed gel eletrophoresis for analysing RNA in detail and used this to study the progress of RNA molecules from the cell nucleus and its processing and transport to the cytoplasm. This work also showed how bacterial ribosomal RNA was distinct from that of plants and animals and that it evolved in size in the latter. Since there are no intermediate forms between prokaryote and eukaryote RNA, the work confirmed that chloroplasts must have evolved from capture or symbiosis of blue-green algae. Call this process *natural genetic engineering* if you like! Following long-held interests, and with the founding and repeatedly threatened closure of the Centre for Human Ecology in the 1970's, he became more and more involved with society's ecological impacts. He became Director of CHE in 1984, and retired in 1995. In 1989 he helped in setting up a large organic farming research and demonstration centre. Now with the re-commencement of the independent CHE's MSc course, he is 'founding Chair' of the Academic Board. He also founded and runs a small "sustainable forest" timber company. He is a member of the Henry Doubleday Research Association and of the Soil Association and has grown his organic vegetables for the last half century!

THE SCIENCE MISSING FROM THE GM DEBATE

Why the opposition to GMO in agriculture may have a sound basis.

Dr Ulrich Loening, Fellow, Centre for Human Ecology, Edinburgh
September 1999. The opinions expressed in this paper are those of the author and are not necessarily those of the Centre for Human Ecology.

Introduction:

"Man has got too clever, and yet not clever enough" (farmer, about fall-out from Chernobyl in Wales, May 1 1999)

Three developments could help reduce public concern about genetically modified crops: broader criteria to assess their social and environmental impact, an over-arching monitoring body, and greater transparency. (Nature, April 1999)

"*It is also possible that genetic modification is a 'lightning-rod' upon which the public's general uneasiness about the modern world is focused."* (Nuffield Council on Bio-ethics, 1999)

This paper explores some areas of science which have been missing from the debate on GMO[1] in agriculture. Given that the arguments are set in the context of feeding the world next century, many areas of biology and ecology that are relevant have been neglected. The deficiency indicates that public opposition, far from being irrational, actually results from a sound and deep instinct.

"…there is also a growing awareness that there could indeed be something real behind the misgivings which many people express, a true intuition that represents something that mere reason is oblivious to. (Bruce & Bruce, 1998, p.xii)

Beneath the hype and concern for safety, there may lie an intuitive and profound understanding that agricultural development is heading in the wrong direction.

History suggests that concerns such as these often prove to be right; instincts are often sound. The quote from Nature above does not take account of the possibility that the *"broader criteria, … monitoring …and greater transparency",* if carried out fully, might have an effect opposite to that intended. The result could well be to increase rather than reduce public concern. The Nuffield Council's "lightning-rod" may indicate a genuine storm

[1] The term 'genetically modified' is unfortunate since all domesticated plants and animals have been genetically modified by breeding. More distinctive terms are 'Genetic engineering', 'gene transfer technologies', or 'transgenic foods', or 'transgenosis' (as proposed by N Simmonds, 1997), and will be used here.

in the science and social science in the GMO debate. More education might well strengthen opposition to GMO in agriculture.

On the other hand, history also illustrates the contrary assumption that opposition to valuable technical innovations has often been mis-guided. More education could lead to more acceptance of GMO foods only if it can fully respond to the opposing concerns.

These two conflicting propositions become confused (see Nature, editorial, 1999) because of an asymmetry between them: many individual technologies can be described with simple and cogent arguments, whereas discussion of alternatives requires consideration of divers scientific, social, economic, ethical and ecological aspects. Thus there is an imbalance in the levels of discussion: the arguments counter to gene transfer technologies are subtle and complex. An over-arching body that does more than monitoring is needed to unpack the issues.

Examples from the literature

That the arguments promoting genetic engineering are easier to make does not excuse the gene technologists from making simplistic statements: I selected some statements made by distinguished advocates of genetic engineering which illustrate certain deficiencies in science as discussed in this paper; they balance the opposition hype that is so often criticised: (Bruce & Bruce, (1998), pxii)

Robin Nott (1998) concluded a lecture with:

"To those who complain that such developments are likely to lead to a loss of biodiversity I can only say that to deny mankind the benefits of biotechnology for the continuation of biodiversity seems to me an unreasonable burden to put on those who will benefit. The benefits which are likely to accrue from biotechnology are likely to be sufficient to fund the "artificial" maintenance of biodiversity in plant collections and the like."

Does one still have to spell out that biological and ecological diversity is more than a list of species? And that these cannot be "artificially" maintained long-term? Perhaps a study of the values of ecological services might be the first step (Costanza et al, 1997).

Norman Borlaug, addressing the Asian Development Bank meeting in Manila was quoted in The Guardian 1 May 1999 as saying: *" If you used the farming techniques being employed in the 1930's, you wouldn't be able to feed more than 2bn people."*

Although this sentence is not in his paper, the implication that no alternative exists between GMO and primitive industrial agriculture remains. Similarly:

"False romantic notions of medieval, subsistence agriculture will not feed an extra 5 billion mouths." (SCRI 1998.)

Both these illustrate a common mis-understanding that regards organic agriculture as a technology from the past and any options other than current conventional ones as useless.

The necessity for patenting if genetic biotechnology is to advance, is often stressed. However: *"..the logic behind moral objections about "owning life-forms" seems far from clear in view of the fact that we happily talk about owning cats and dogs and orchids and orchards without arousing moral indignation." (BBSRC, 1996)*

wholly misses the argument that whereas it is legitimate to own individuals of a species, it is the species and the rights thereto, which are patented.

While one can expect media hype to produce distortion, there must be serious concern when distinguished scientists, lawyers and decision-makers counter the opposition in such manner and expose such mis-understanding

The Context

The above quotations show how the debate has become polarised, and they are fun to quote. But they have deep roots and expose three arguments:

1. That the debate and spate of publications, (and the plea by the Royal Society to distinguish good science from bad science) have failed to encompass the range of scientific endeavour that is needed; and that indeed this inadequacy is due to deficiencies in the science covered: much of importance and relevance is not considered.
2. That the public are sceptical of the very basis of this scientific endeavour and that this distrust is based on sound instinct. The questions about safety and health may be merely expressions of deeper concern about new roles for science and technology.
3. That the way to allay public distrust is not by conventional scientific education alone, but by informing on a wide front, challenging basic assumptions about progress and development.

One could argue that general questions about the future are not within the domain of genetic engineering science. However, proponents of the technology, both academic and corporate, argue for the new biotechnologies in the context of feeding the world into the next century. *"New approaches are needed in addition to the improvement of existing methods…"* (Royal Society, 1998). The Royal Society agrees with the BBSRC Concensus Conference (1994) that: *"…the regulatory authorities should address the wider issues surrounding the introduction of GM commodity crops by putting in place a monitoring mechanism or over-arching organisation, …."* And: "*In addition, an overarching body is needed to have an ongoing role in monitoring the wider issues associated with the development of biotechnology in agriculture and food* *production."* (GMOs and the environment**:** A response to the inquiry by the House of Commons Environmental Audit Committee, April 1999). Similarly the Nuffield Council "*…. recommends that an over-arching, independent biotechnology advisory committee is established to consider within a broad remit, the scientific and ethical issues together with the public values associated with GM crops".*

The need is clear. The debate on where, whether and how gene transfer technology can contribute to feeding the world next century must embrace every aspect of the global "*problematique"* of population, resources, environment and development (PRED in UN jargon). Most analyses agree that, by any biological, ecological, economic or development criteria, a turning point has been reached (Masarovic & Pestel, 1974; Meadows, et al, 1992; Bossel, 1998)

Attempts to consider the whole are often dismissed as unrealistic; we tend to work on the margins taking small steps at a time. However, here I will present some "over-arching" ideas, beyond what the BBSRC and the Royal Society indicate and beyond what the Government now proposes with two new committees.

The scientific debate can be arbitrarily divided into five overlapping areas, each of which demonstrates some deficiencies within the science of applied genetic engineering:

1. **The biotechnology of gene transfer** itself, which is still in its early stages. The complexities of multi-gene actions remain beyond understanding and application and are not publicised.
2. **The biology of crops,** especially the mechanisms of nutrient uptake and pest resistance, which are inadequately researched in the context of alternatives to gene transfer technology.
3. **The ecology of agriculture** as it impacts on natural processes; especially how ecosystems become less resilient under management .
4. **The ecology of the human species**, ultimately dependent on agriculture and ecosystem services, but attempting to overcome rather than harness these services.
5. **The economic and social implications**; showing internal contradictions which require re-examination of some basic assumptions.

The arguments

1. The biotechnology of gene transfer.

For instance, these are still early days for much of this technology. Many of the benefits are currently more hoped for than proven. Some may be very successful, others may turn out too difficult or too expensive. Biotechnology has become prone to promotional exaggeration (SRT Project, submission to General Assembly, Church of Scotland, 1999)

Gene transfer can at present insert only single genes (coding for desired proteins) randomly into the genome. The added gene will usually be out of the context of the structure of the genome. Therefore no account can be taken of the epigenetic functions of the genome, of the action of the genome as a whole complex system. There is no simple relation between any one gene and any one phenotypic character. While this is accepted, it is usually not made explicit within the debate.

One can envision much progress in understanding and application, as outlined for example by Mazur (1999); but these research efforts can go only a limited way.

The strategy of the genes is not understood sufficiently, and perhaps cannot be, for a site for a foreign gene to be defined. A randomly inserted gene (including promoters and insertion sequences) will often have unpredictable embryological effects, other than production of the desired protein. It should be no surprise that, for example, a potato variety becomes "not substantially equivalent" to the parent (as found in the controversial experiments by Pusztai, although this result could equally be due to other changes in the particular cell from which that clone was derived). Conventional breeding in contrast, by its very nature, maintains the overall integrity of biological functions during growth and embryogenesis, without the need for the breeder to understand the details and however bizarre or extreme the selected progeny.

The idea that gene transfer technology is a more precise extension of classical breeding is false in at least two ways: (a) it does not occur normally in nature; the separation between species is usually absolute - this is a new process. Genes do not suddenly appear in the genome but evolve; and (b) it is not more exact than breeding but less so (other than for the particular protein desired) since the inserted DNA integrates in random places.
Thus the judgement of The Nuffield Council is incorrect; it *"concludes that there is no clear dividing line which could prescribe what types of genetic modification are unacceptable because they are considered by some to be 'unnatural'." "[The Council] takes the view that the genetic modification of plants does not differ to such an extent from conventional breeding that it is in itself morally objectionable".*
This blurs the distinction between gene transfer technologies that practically never occur in nature and breeding which is the normal process of genetic recombination. They are biologically opposites. One might invert the common ethical interpretation: it is conventional breeding that may be dubbed "playing God", (because the intense selective pressure at least reflects natural selection) rather than gene transfer technology which is new and cuts through the processes of evolution; not how God may be thought to act!

While the processes of breeding and of genetic engineering are biologically opposites, what they have in common is the desire for the product - the new variety.

The distinction remains even if intermediate manipulations are possible, such as mixing different species' chromosomes by cell fusion. Those who object to gene transfer on either scientific or on moral grounds or both, might ask themselves how they regard attempts to create, for example, hybrid wheat produced by cell fusion with perennial grasses, to create perennial wheat which are ecologically fitter on prairie soils (the Land Institute, pers. comm. 1999). Like breeding and indeed like the classical breeding of wheat from three species, this maintains the genetic co-ordination of the organism. Judgement must be based on correct understanding of the technical science involved.

In conclusion, the contrast between successful intervention by gene transfer technologies and the equally successful breeding has been ducked in the debate with the notion that the former is a continuation of the latter. But, since there is system in the genetic processes which are necessarily by-passed by genetic engineering, any continuity that there may be is not in the technologies but in the underlying scientific attitude of trying to *short-circuit natural processes and constraints*.

2. The biology of agriculture.

Agricultural science and technology has always aimed to over-come natural constraints - that is what agriculture is about, whether traditional, conventional or organic. Increasing use of artificial fertilisers and pesticides and more sophisticated breeding techniques demonstrate the spectacular successes in a long tradition of that aim. Now gene transfer technology is acclaimed as in the same direction.

However, within this tradition much valuable biological experience has failed to be learnt. Consider first a historical example in the uptake of nutrients by plants: the studies initiated by Liebig and developed by the Rothamstead Experimental Station, scarcely recognised the roles of mycchoriza in mineralising bound nutrients and passing them directly into root cells. The application of the science was simplified to fertilisation with soluble nutrients, and this led both to success in increased productivity and to problems with pests, diseases and soil erosion.

The science of pest control provides a related example of simplification and of over-riding natural processes. Plants operate their own "integrated pest management" systems and one of the most widespread means, but least recognised, is by not feeding the pest or disease organism: for example, it is clear that increased nitrogen fertilisation leads to increased "susceptibility" to pests, as in 'green revolution' rice. Similarly, herbicides and most pesticides cause increased pest multiplication, probably by temporarily inhibiting protein synthesis. In both agricultural treatments, the levels of cellular amino acids are raised and feed the pests, (Chaboussou, 1985)[2]. However, the biology of plant resistance to pests and diseases is conventionally focused on natural predators and internal poisons. The internal nutritional state is scarcely considered. So a

[2] Note that the term "resistance" is often used when "poisonous" is meant; the method of control is different.

conference held by the Royal Society on biological pest control, (1987) did not mention the physiological state of the plant as a factor; although some of the data clearly showed how nutrient balance rather than predator activity might be the controlling factor. Similarly the Boxforth Project (1985--) to investigate the options for lower-input farming, was not designed to test whether lower fertiliser and pesticide use led to greater resistance of crops to pests.

The case of using the Bt gene is especially instructive. There is a large literature on *Bacillus thuringensis,* its toxic lectins and the application for control of numerous pests. Different strains of the bacterium have been identified and selected, and each produces multiple toxins. The application of Bt as a pesticide spray, especially by organic farmers, inevitably uses both this diversity and the instability of the bug, thereby maximising effectiveness just when needed and minimising development of pest resistance. In contrast, the gene for only a single Bt toxic protein is used in genetic engineering; this toxin is then produced in all (or nearly all) tissues of the plant in different species of crops, continuously throughout the growth period, and in practice over large areas where the crop is grown. This technique therefore replaces the widespread use of externally sprayed pesticides with a widespread internal poison. Far from avoiding the use of pesticides, the process effectively spreads a new pest poison pervasively throughout farmlands: a single focused technology takes the place of a diverse biological approach.

Reaction to the problems created by soluble fertilisers and pesticides led to the development of various schools of “organic” agriculture. One might argue that the “organic” opposition to transgenics arises out of this historical trend of short-circuiting rather than harnessing natural processes.

These examples indicate avenues for biological R&D on basic aspects of plant nutrition and health. No-one would disagree that these areas are vitally important, but in practice they have been neglected in favour of gene technologies.

3. **The ecology of agriculture**.

Despite the aims of advocates of organic agriculture, permaculture, biodynamic agriculture and related technologies, it remains the case that:

> *"The marked instability of agro-ecosystems (and other artificial communities) in contrast to the stability of natural communities, results from the lack in crop systems of co-evolutionary links between inter-acting species.   However, co-evolution may be either stabilising or destabilising: sometimes the loss of one species may lead to decay of an entire system."*
> (Ehrlich, 1977)

Throughout its long history, almost every agricultural innovation has succeeded in feeding a larger population; and most innovations have been individually benign in their environmental or other impacts. Taken together however, they have created the problems of unsustainability with which everyone is familiar: of salination, desertification, soil erosion, loss of biodiversity, loss of ecological stability, and most recently, even loss of agricultural diversity itself. Many of the problems have been recognised for long enough, (Plato, The Criteas, ~450BC). Even the apparently sustainable agriculture in China, studied by King (1911) and which led him to predict the USA dust bowls, was at the expense of forests. At present, soil erosion continues at some 25bn tons/annum globally, about 5 tons/capita/annum.

The essential questions here are about the possibilities for the management of eco-systems in such a way as to provide resources in ecologically and economically stable and/or sustainable ways. The prognosis is not promising: of 24 different managed ecosystems studied, all showed reduced resilience, and increased "brittleness" - pushed closer to the edge of degradation even when little change is yet apparent. (Holling, 1992). The effects of changes or new challenges to existing eco-systems may lead to 'bifurcations' into new directions that are usually unpredictable. Ecosystems grow and evolve and cannot be created or assembled from the parts. In contrast, agriculture first modifies, and now increasingly 'manufactures,' new ecological structures.

Increased management and intensification has increased yields but also decreased resilience to the extent that food security may be threatened. The question now is whether transgenic plants which introduce single new genes into a small number of species for widespread cultivation, will in the longer term exacerbate this trend, much like the transport of species across continents. While the science of transgenics alone might suggest that some environmentally friendly results like reduced pesticide use could result, experience in the bigger science of ecological processes suggest that the major result will be further loss of diversity and loss of resilience and therefore loss of food security.

The Nuffield Council on Bio-ethics, (1999) for example, concentrated only on the immediate dangers and avoided engaging in the larger questions:
"*.. Consumers in the UK and much of Europe appear to be increasingly concerned about the safety and impact of GM food. This is almost certainly linked to two major factors: first, the high-profile campaigns of environmental and other pressure groups and secondly, the development of intensive farming, which, although it has delivered high quality food at ever decreasing prices, has been accompanied by:*
• *well-publicised food scares, particularly BSE (bovine spongiform encephalitis);*
• *a rise in food-poisoning statistics;*
• *overcrowding of animals and a concomitant need for antibiotics to ward off disease."*

However, The Royal Society recommended among other matters: *" • review of mechanisms by which GM crop plants could be monitored in the environment and recommendations for long-term monitoring of impact on ecosystems "* (Scientific advice on GM foods: A response to the inquiry by the House of Commons Science and Technology Committee, April 1999.)

The various field trials in the UK and Europe are clearly inadequate for the task needed and certainly cannot contribute much to "a rational debate." Their destruction by activists is no great loss to rational debate. On the contrary, one can hope that the confrontation will now trigger a broader enquiry into the ecology of agricultural practices as a whole and so improve "rationality".

Meanwhile, the 'over-arching' ecological impacts of intensive agriculture are not considered except in passing and are missing from most of the debate. None of the various reports quoted, nor most others, question the nature and scope of the scientific enquiry that would be appropriate for the task of evaluating GM technologies.

4. The Ecology of the Human Species

The GMO debate is usually set in the context of how to feed the world next century. Some go further and set it in the context of the global problematique: The Lyon Bio-Vision seminar "Building a Common Future" (Desmarescaux & Hodgson 1999) was set in the context of the Brundtland Report and "sustainable development". The Brundtland Report opened with the idea that:

> *"Humanity's inability to fit its doings into this [nature's] pattern is changing planetary systems, fundamentally."*

The Nuffield Council challenged: "*The question of how to decide whether GM crops are "unnatural" to an unacceptable degree is more difficult to address".*

The very success of applied science has been to over-come, rather than to "fit into nature's patterns". This has been so throughout the growth of modern science and in which the founding of the Royal Society at the end of the 17^{th} century played an important part. As the technical applications led to continued successes, so the approach was self-confirmed.

If it is accepted that "fitting into nature's patterns" in some form is required for both ecological and socio-economic sustainability (there are many who do not accept this), then newer tools beyond conventional science and its applications, are called for. Other sets of criteria or judgements of what constitutes good applied science are needed. The old criteria of rigour in the science, feasibility of the applications, and some promise of potential benefits, albeit based on assumptions from past experience of other technologies, are valid, but have become insufficient.

One way out of this deficiency has been to establish indicators of sustainability, as ready tools to help to monitor progress and assess the consequences of development. (Meadows, 1998; Slesser et al, 1997; Bossel, 1999; de Vries, 1998). Indicators were developed with key parameters to assess the physically possible and its limits and how human activities interrelate with natural resources (Meadows et al, 1992; Peet, 1992). Little, if any, of the debate on genetic engineering has been in the context of indicators of sustainable development, except perhaps by the opposition. While economic modelling is the norm and economic projections are made at every level, the biological, ecological and physical bases on which these ultimately depend has been neglected.

The same goes for all aspects of agricultural development: the point here is that the value or otherwise of gene technologies cannot be put into the global context of "feeding the world" without as full as possible an assessment of this kind.

It is to be noted that most of those who do engage in resource modelling and the development of indicators of sustainability, also conclude that most modern agriculture is not sustainable and that genetic engineering is not likely to help.

So, any "over-arching" assessments would need similarly over-arching indicators or criteria. Indicators are convenient summarising tools, designed so that not every question need be thought out from first principles. Appropriate check-lists and indicators about the extent to which the technology fits more or less closely into the patterns of natural processes, can serve to judge whether a technical process is "unnatural to an unacceptable degree."

One could for example develop indicators about whether a technology "fits into nature's patterns" from the following questions:

1. To what extent is it cyclic rather than linear, both materially and conceptually? Modern food production has converted a material cycle into a linear process from resource to sewage. Gene technologies break the breeding cycle by inserting a foreign gene: the concept of feed-back by selection on a fluid genome is avoided.
2. To what extent are the waste products and side-effects in fact synergistic benefits? Wastes and by-products are not natural but are human concepts of what we happen not to want. Transferred genes are unlikely to have synergistically useful side effects, as indicated above.
3. In place of micro competition and macro co-operation, to what extent does the technique over-ride or short-circuit and conquer a natural process? Gene technologies seem supreme examples of short-circuiting natural breeding and selections processes.
4. In place of a quantitative balance of interacting forces, to what extent does the technology lead to excesses? Society in general is proud of successes that lead to excesses despite the resultant problems. Genetic technologies are likely to lead to large excesses of small numbers of genes or species; just as with antibiotic usage.
5. Homeostasis and homeorhesis (continued development in a direction) are characteristic of ecosystems, (and indeed of the biosphere) which many technologies are designed to over-come. Global change has been the result. Gene technologies by their nature are designed to accelerate change.
6. Natural diversities, (including in addition to species numbers, ecosystems, natural dynamic processes, human cultural diversities, etc.,) tend to be maintained or increased; many technical activities reduce diversities; gene technologies again of their very nature, must reduce agricultural diversity, and probably also natural diversities.
7. The sustainable functioning of the biosphere and its components is controlled by multiple and complex feed-backs, mostly negative, which the successes of human endeavour have either avoided or replaced with positive feed-backs. Yet negative feed-backs are a positive boon (Harding, 1985) without which few things would function properly. This is recognised to a limited extent in "market regulation" or legal constraints, but scarcely for biological or other social matters. Would gene technologies incorporate of themselves appropriate negative fee-back? There are clearly wider issues here for regulatory bodies, than regulation merely in regard to short term safety.

The above 7 points can be regarded as an expansion of Aldo Leopold's famous criterion: *"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."*

This describes a dynamic, not a static, condition, as do the 7 criteria above: all are concerned with tendency. Each might be developed further into more detailed indicators. Such questions about whether and how to take on a new technology which is certain to have far reaching consequences, have been essentially missing from the debate.

It should be noted that most of the international environmental conventions, especially the Biodiversity and Climate Change conventions, the Montreal Protocol, and CITES, have implicit within them the above 7 criteria, with attempts to shift international activities towards ecological sustainability. Much of the WTO agenda is however incompatible with these conventions.

The conclusion of this section is that the science of how to "fit humanity's doings into nature's patterns" has not been addressed adequately, the tools for doing so exist but require development, and they have not been applied to genetic engineering.

One might argue that the choices between transgenetics and ecologically motivated alternatives are not mutually exclusive. Unfortunately they are, both in theory since they are philosophical opposites and in practice, since the band-wagon of gene biotechnology (Simmonds, 1998) has taken resources and motivation away from classical breeding and from other means of fertilisation and pest control. It is also the case that many alternative techniques offer no marketable product and instead require more farming skills and labour, so corporations cannot be interested. These two issues take us to section 5.

5. **The Economic and Social implications.**

The innovation of gene biotechnology into regular agricultural usage is in practice limited to the major corporations. Without patenting and corporate ownership, the present generation of genetically engineered crop plants would not exist. Viewed from within the economic systems, this is consistent with freedom of trade and reduction or removal of barriers to trade, as well as with recognition of intellectual property rights. Viewed from outside the system, however, the arrangement paradoxically becomes closely similar to a centrally planned economy. While there is a large and growing number of relatively small companies that are developing biotechnological products, (see for example several articles in Nature Biotechnology, vol. 17, May 1999) the major marketing of agricultural seeds and products is in the hands of very few large companies. Thus in place of government controls and regulation in a planned economy, one has large international corporations: the effect of central control of products, of choice of technologies and of reducing social and biological diversities is comparable. The tendency is towards a monolithic agriculture, in which farmers have little or no choice about their seeds, fertilisers, pesticides, methods of cultivation, or even marketing of the products. With dependence on a few large sources of inputs, the system necessarily becomes less diverse and more liable to ecological or even economic/ social collapse, like any ecosystem in which a crucial component fails.

The social sciences of globalisation have been thoroughly studied and consequences documented (George, (1992), Korten, (1995), Mander & Goldsmith, (1996), and many reports from the World Bank and UNDP). The conclusions are not missing from the GM debate: they are vigorously proclaimed by its opponents; but most advocates of genetic biotechnologies and especially those concerned with intellectual property rights and patenting, see the global economy as the only way to advance agriculture and are silent or ignorant about the social and ecological implications. Since the issues are complex, diverse and full of disagreement, with crucial global decisions taken behind closed doors, the public also can only be poorly informed.

For example, The Nuffield Council did not understand the situation: "*The moral imperative for making GM crops readily and economically available to developing countries who want them is compelling*". This imperative cannot be met, since gene biotechnology is tied to the present global economy.

If as usually argued, it is poor distribution of food aggravated by poverty that is the immediate problem of food scarcity, then one can only conclude that the market control of seeds and agrochemicals by so few companies has been part of the causes of this situation and cannot be a solution. And gene transfer technologies can only increase that market control. The assumptions underlying the aim of creation of wealth from biotechnology (an explicit remit of the BBSRC, when its name was changed from Agriculture and Food Research Council), have not been exposed in the GM debate.

Finally, a further and crucial factor has been neglected in the debate: farming is more than merely the production of food; the skills of the farmer, the social context of self-reliance and of the dignity this promotes, broadens it to agri-culture. The trend for decades has been to reduce this social complexity. The reduction in agricultural skills (and of course reduction of employment) may be of immediate economic benefit but it also leads to dependence and insecurity. While gene technology may be one small step for agricultural technologies, it is also a large leap in removing the close bonding between people and land.

The monolithic consequences of genetic engineering for agriculture have not yet been adequately evaluated by any "over-arching" committee, other than by independent NGO's and opponents of the technologies. The deficiency remains and public concern therefore seems well-founded.

Summary and Conclusions:

Several general principles emerge:

1. What is good science in itself, like that which led to gene transfer technologies, can become deficient when that technology is applied. New issues become relevant, another science is needed and different categories of experts are be called for.
2. To assess the values of gene transfer technology for improvements in agriculture, it is not sufficient to compare its postulated advantages with the situation if these were foregone by not using it. The comparison has to be with other technologies for agriculture and the opportunity costs of all options. The balance is usually between the simple (gene technology) and the complex (a spread of approaches). The latter are always more difficult to describe and promote, but may be more valuable.
3. On the basis of a broader and rigorous science, gene technologies in their present preliminary form, appear to be not very useful and are potentially ecologically damaging. In more advanced forms, they are likely become more challenging, either by using plants to synthesise seriously poisonous pharmaceuticals and related products, or by succeeding to manipulate multiple gene complexes. Risks will then become greater, and ethical arguments extended.
4. In the end, the contrast is between two world views about progress: either to strive towards managing each and every identified mechanism of an ecosystem such as farming so as to gain total control, or to promote ways of living by bending ecosystems towards growing humans, a more complex approach. The former leads to a penetrating over-riding technology and the latter to the harnessing of ecosystems including their emergent properties. The latter may be called a human ecological approach. It incorporates more fully the true complexities of natural processes, the science of systems. This is the science that is missing from the debate.
5. The fundamental question remains, what mix of approaches provides the greatest food security? The choice between the two approaches ultimately rests not within science but on judgement, albeit a judgement informed by rigorous and "over-arching" scientific analyses. The case made in this paper is that the more the relevant areas are explored in depth, the less does genetic engineering appear an option. The advocates of gene technologies have not tackled the issue in this way; and those who have tried, usually come to oppose the technology and present other powerful ways forward.

Appropriate technologies that could take agricultural practice from domination towards co-operation with natural processes and with sustainable high productivity, are known; and experience has accumulated in all countries. As an example of how much can be achieved by breeding and soil conservation, my photos showing the benefits of oxen-based soil conservation farming in a semi-arid region of Cameroon, are nearly identical to those shown by Reeves (1999) for maize bred to stand drought conditions, (compared to a Cargill variety): plump cobs compared to meagre ones. Reeves stressed the need for a new research paradigm, which *"must focus on achieving an optimal combination of the best genotypes (G) in the right environments (E) under appropriate crop management (M) and generating appropriate outcomes for people (P)…" "Sustainable intensification ..is the only… choice."*

All of these ideals have the potential for positive synergistic results, which transgenesis lacks. Perhaps another catch-phrase is needed to encapsulate the thrusts for ecologically and socially improving agriculture. "Organic" is of course one such, but since this term is now strictly defined by standards, I suggest that José Lutzenberger's "Regenerative Agriculture" would give new impetus.

One has to conclude that with so much missing from the debate and with so many proven options for agricultural development, the case for gene transfer technologies fails. Public opposition seems indeed to be based on sound intuition.

References

BBSRC, (1996) "Ethics, morality and crop biotechnology.", Biotechnology and Biological Sciences Research Council (Swindon).

Bruce, D & Bruce A (1998) Engineering Genesis, (1998) SRT Project, Church of Scotland, (Earthscan Publications, London)

Bossel, H. (1998) Earth at a Crossroads; Paths to a Sustainable Future, (Cambridge University Press)

Bossel, H. (1999) Indicators for sustainable Development: Theory, Method, Applications. A Report to the Balaton Group, (International Institute for Sustainable Development, Winnipeg, Canada)

Chaboussou, F. (1985) Santé des Cultures; une révolution agronomique. (Flammarion, Paris)

Costanza, R et al., (1997) Nature, 387, 253-260.

Desmarescaux, P & Hodgson, J. (1999) Nature Biotechnology Supplement Vol 17, BV1.

De Vries, B. (1998) Targets; IPCC Working Group 3.

Ehrlich, P. R. et al (1977) Ecoscience, (W H Freeman, San Francisco)

George, S. (1992) The Debt Boomerang, (Pluto Press)

Harding, G. (1985) Human Ecology: The Subversive, Conservative Science, in "Science as a Way of Knowing", Amer. Zool. Vol 25, p 469-476, (American Society of Zoologists)

Holling, C.S. (1993) New Science and New investments for a sustainable Biosphere, in Investing in Natural Capital, Constanza et al, (ISEE Press, Solomons, MD)

King (1911) Farmers of Forty Centuries, (reprinted, Rodale Press, Pennsylvania)

Korten, D. C. (1995) When Corporations Rule the World, (Kumarian Press, Connecticut)

Mander & Goldsmith, eds, (1996) The Case against the Global Economy (Sierra Club Books)

Mazur, Barbara, (1999) Nature, 17 Supplement, pp. BV9-10

Meadows, D. et al (1992) Beyond the Limits, (Earthscan, London)

Meadows, D. (1998) Indicators and Information Systems for Sustainable Development: Report to the Balaton Group (Sustainability Institute, PO Box 174 VT USA)

Mesarovic & Pestel, (1974) Mankind at a Turning Point; 2nd Report to the Club of Rome (Dutton, New York)

Nott, Robin (1998) from : Patents: help or hindrance, Cameron McKenna, 23 Sept 1998)
Nature, commentary, April 1999
Nature, Editorial, (1999), "Genetically modified muddle" Nature Biotechnology, 17, 311
Nuffield Council on Bioethics, (1999) , ,
Peet, J. (1992) Energy and the Ecological Economics of Sustainability (Island Press, Washington DC)
Reeves (1999) Nature Biotechnology 17, Supplement, p BV33
Royal Society Symposium on the Biological Control of Pests and Diseases (1986)
Royal Society, (1998) statement on "Genetically modified plants for food use." (London, Sept 1998.)
Scottish Crops Research Institute, Annual Report, (1998) Chapters in "Development, release and regulation of GM crops" and "The need for plant pathology", (SCRI)
Simmonds, N. W. (1997) Pie in the Sky, Tropical Agriculture Association Newsletter, June 1997, 1-5.
Slesser M. et al, (1997) The Management of Greed (Resource Use Institute, Perth Scotland)

Acknowledgements

I acknowledge that the arguments I make are biased; it is impossible not to be so. The most rigorous and reductionist science on which genetics and the applications of gene technologies depend, is likewise biased because it has to omit so much. So I thank those many colleagues who over several decades have informed, encouraged and provoked, who have been the stimulus to explore as many avenues as I could. They include former students who are now in senior positions in biotechnology and equally those who are at the forefront of questioning basic assumptions. I do not name them, but I want them to know how much they have contributed. Of course I remain responsible for the arguments, with which many of my colleagues will disagree.

© 1999. Dr Ulrich E Loening. This paper may be quoted and copied freely with acknowledgement.

Note added overleaf.

Note added:

Since this paper was written, the ESRC Global Environmental Change Programme published the paper “The politics of GM food. Risk, science & public trust” in October 1999, as Special Briefing No. 5 edited by Alister Scott et al with contributions from 10 others. Their conclusions are closely similar to those presented here, as follows:

“.. the evidence from research is that many of the public, far from requiring a better understanding of science, are well informed about scientific advance and new technologies and highly sophisticated in their thinking on the issues. Many ‘ordinary’ people demonstrate a thorough grasp of issues such as uncertainty: if anything, the public are ahead of many scientists and policy advisors in their instinctive feeling for a need to act in a precautionary way. What is more, our research calls into question the validity of the notion of ‘sound science, …’ “.

Exactly so!

The Briefing also states:

“We suggest that science cannot provide definitive answers in these cases, so the policy of relying on claims of ‘sound science’ may, ironically, itself be unsound. Ethical issues are central.”

While of course ethical issues are central, this paper indicates that the science was deficient, not ‘sound’, in that so much was omitted. There is only a hint of this conclusion in the Briefing:

“But the way that scientific advice is used is heavily influenced by the way the official advisory system is put together. Until recently, this has been determined by a precise yet narrow interpretation of the sorts of knowledge required to form judgements about GM technology. For example, no ecologists have been included in the various advisory committees.”

Exactly so!