GENETIC ENGINEERING - GENETECHNOLOGY IS IT SALVATION OR CURSE FOR THE 21th CENTURY?

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INTRODUCTION

After Watson and Crick's discovery of the double helical structure of DNA, and that inheritance in all life forms is determined by a universally valid genetic code based on the "big four" purine/pyrimidine bases, an optimistic hope was raised that for the first time in history humanity could look into and discover the secrets of creation and improve life-forms to suit their needs. The claim that one gene codes for a single protein (*genetic determinism*) regardless of where the gene is expressed appeared to reinforce the belief that humanity has taken the first steps on the way to understand what makes us humans and what differentiates us from other life forms of the world.

With progress in genetic science it became possible for the first time to transfer genetic information derived from various sources into microorganisms. With this major advance in the seventies of the last century a new scientific research field has opened up, what we now call as the recombinant DNA technology. By taking a gene from any source and transferring and splicing it into a recipient organism the possibility that the phenotype of any living matter could be changed became reality. When industry realized the potential of this technology for the development of genetically engineered (GE) products that could be patented and sold at a profit genetic engineering of agriculturally important crop plants has started in earnest. Most pesticide-producing industries have quickly turned to this new lucrative business, particularly when it was realized that by splicing genes of enzymes into important crop plants capable of degrading herbicides that were the patented products of their own they could make these transformed plants resistant to the company's own herbicide. This combination of two complementary products increased the commercial potential and the company's profit. By 1995 the first GE crop, the FLAVR-SAVR tomato, was commercialised. The take up of GE crops has since been phenomenal and nowadays the four main GE crops, soybeans, maize, cotton and oilseed rape, are being grown on about 100 million hectares, mainly in the Americas.

NOT EVERYTHING IS GOLD THAT SHINES

The apparently striking success of this new technology has unfortunately blinded many peoples' view to potential pitfalls. All the same, problems soon emerged. Thus, even at the beginning there were sceptical and sometimes even dissenting voices sounding caution regarding the often and overconfidently declared absolute safety of the GE crops by the industry. Ecologists, population geneticists, plant physiologists and nutritional scientists, quite rightly, expected more and reliable published results of risk analyses from biotechnology researchers rather than non-fact-based opinions and assertions. Reality really started to dawn on genetic scientists with the completion of the human genome project showing that the dogma of genetic determinism, the science basis of genetic engineering was untrue as the less than 30,000 genes could not possibly code for the about 200,000 cellular proteins. It was also realized that the about 97% non-gene "junk" DNA has a decisive role in the genome. Our primitive splicing techniques together with our inability to direct the transgene into “safe” zones in the genome, if such zones exist at all, were shown to lead to insertional mutagenesis with unpredictable consequences. Although it is impossible to forecast in advance what these consequences for health and the environment will be a few independent studies have already shown, unfortunately only after the already de-regulated GE crops have been commercialised that in many instances, quite unintentionally, new antinutrients, toxins, and allergens were formed as by-products of gene-splicing and other, mainly unpredictable immunity-related problems also occurred. Indeed, most people now accept the necessity of some form of generally acceptable biological safety testing before a new GE crop is released. However, the industry still hangs on to the less costly but unscientific principle of substantial equivalence, *i.e*. the near identity of the GE crop with its parent line, as their main “safety testing” and only commission simple contract animal feeding/production studies as a last resort to support their case of human/animal safety. In fact, there are hardly more than over two dozens of published academic animal safety studies and the results of only one human trial have been published, and even that was not a full clinical study (Netherwood et al. 2004). Very few immunology investigations have been carried out and described and the effect of GE food on reproduction is almost untouched by science. The worrisome results of one such study on rat reproduction by a Russian researcher has been almost totally written off by the GE biotechnology industry without even ever considering repeating it. Most independently performed biochemical/physiological safety studies have revealed many worrying health problems to which the GE biotech industry had no answer but to rely on its considerable political and financial power to force its products on consumers. They also hinder independent studies that could establish new and less primitive genetic engineering methods and to work out new scientific methods for the risk assessment of GE crops. According to the GE-biotechnology industry *GE crops are safe and this is a fact.* Accordingly, there is no need to finance safety-testing studies.

ROLE OF THE PUBLIC

A particularly grave problem for the GE biotechnology industry is that a large majority of European consumers has rejected foods based on GE crops and therefore farmers in many EU- and some other countries are reluctant to grow them. The main reason for this lack of consumer acceptance is that people instinctively distrust foods that had been produced unnaturally and had not undergone transparent and independent testing for safety. It is understandable that green NGOs are opposing GE foods that they regard unnatural but some independent scientists have also started voicing their concern, reinforcing consumer rejection. Even in the USA most of the four successful GE crops are used mainly in animal production and other GE crops that could be used as human foods, such as GE wheat, GE potatoes, etc, were withdrawn or not commercialised at all. This happened despite the GE biotech companies’ considerable commercial and political muscle and a lax food regulatory system. Although few people would quarrel with the often-declared apparently noble objectives of genetic engineering, *i.e*. to increase food production to satisfy the presently undernourished or starving masses of people in the Third World, improve the nutritional content of agricultural crops, or reduce the use of chemicals in agricultural production and achieve all this not by cutting down the rainforests but by making possible the production of crops on marginal-, salty- and water-starved, parched lands that previously could not be used for agriculture. Unfortunately, nothing of these promises has become reality so far and all these objectives are largely promises for the future. The reality is that in practice only two main types of GE crops exist: those that resist the companies' own herbicides (*e.g*. RR soybean and other herbicide/resistant crops) or those that produce their own pesticides (*e.g*. GE corn, or other crops genetically engineered with one or more of the genes coding for the appropriate *cry* toxins of *Bacillus thuringiensis*). More recently there are also attempts to introduce into agricultural production of GE crops in open field that produce chemicals, drugs, vaccines or other immuno-chemicals engineered into our food crops. Although it is promised that with these new GE crops drug production will be revolutionized and the products will be considerably cheaper than those manufactured by conventional chemical methods, this new phase of genetic engineering presents very considerable and grave dangers for human/animal health and the environment. A long history of previous mix-ups and accidental contamination cases in the USA clearly show the near impossibility of keeping the engineered and the conventional crops segregated without duplicating all the facilities for their handling and distribution, not to mention the almost certainty of genetic contamination of other crops and weeds by accidental horizontal gene transfer that has already occurred.

INDUSTRIAL DEPENDENCE OF ACADEMIC SCIENCE

Commercialisation of scientific research has developed gradually since the mid-20th century. It accelerated with the Conservative Government of Prime Minister Thatcher in the UK and with President Regan in the USA but then spread all over the world. Research institutes and Universities became more and more commercially orientated and dependent on industrial money. It was first decreed by the UK government that applied research should be subject to the "customer-contract" principle (Rothschild, 1971). For public sector research institutes, initially the main "customers" were government departments, which made contracts for specific policy-relevant research projects. In retrospect, this can be seen as a first step towards commercialising public-sector research. The idea was that the only good science was the one that can yield financial benefits. True, there is nothing wrong with applying science to technical and technological innovations. There is certainly no need to emphasize the importance of technology in our life for which underpinning by good science is essential. However, when this relationship between science and technology is the wrong way round, when science without an immediate technological end product is regarded as something not worth to support, human society enters a dangerous phase. The mentality behind this mission- and product-orientated science ruled supreme until the beginning of the 1990s. However, by then the politicians were beginning to realize how large were the costs of this type of research and how huge a burden this placed on state finances that could and should be passed on to the very industry that benefits from it and not paid from the public purse. No one will argue against industrial support or industrial involvement in science. Commercial funding of research is not wrong *per se*, but it must be done in a balanced way. Commercial research must only be a part of the whole scene with academic research leading the way. However, when most of the funds that used to come from the Government now come from industry and when awards of the remaining state financial sponsorship of research become dependent on whether the project is supported by industrial money or not, from there on science no longer simply just depends on industry but its subservient relationship is close to prostitution. The effect of all this has been disastrous for science. Society no longer believes in the impartiality and trustworthiness of scientists even though some people think that this judgement is probably somewhat harsh. The cards, however, are stacked against the scientist. It is the company that has all the aces, because they have money and lawyers. If the scientist goes against the sponsor’s interest and is taken to the Court by the company which scientist can afford litigation? Even research institutes cannot do this because they haven't got enough money to finance the expensive, risky business of legal challenges. This is against the public interest and is certainly against the scientists' interest.

QUICK FIXES

It is often said nowadays with good justification, that science has become a way to get a quick fix for outstanding problems. For example, if one wants to get rid of aphids that harm potatoes, one can splice a natural or synthetic insecticidal gene into crop plants in the laboratory, so that this problem can be fixed. However, the real problem comes when the resulting plant is grown outside the confinement of the laboratory or the greenhouse. The proper scientific way is that before this is done one ought to first find out what possible harm can arise out of this action and what the risks are for the environment and the living world (e.g. to establish whether the harm by the GE crop comes not only to the pest but also to beneficial insects, *e.g.* see Birch et al 1999). However, it is not always in the financial interest of the industrial sponsor to find out whether there are any downsides to this “fix” because in a competitive industrial situation such research may delay the launching of new products and a competitor may get there first. So the agenda is in many cases is not a science- but a commercial agenda. Nobody doubts that scientists can achieve such narrow objectives and “fix” for example the aphid problem. The question is what price society will have to pay for this technological fix? It is often said that such views are ‘anti-science’ and that risk-aversion/avoidance will stop progress. The question is who is to take the risks? The reality is that usually it is the society and not the developer! Successful scientists in the past used to look at the problem in a scientific context in the confinement of the laboratory. They were allowed to properly complete the research there rather than to rush forward with applications before the job is finished. It happens very often nowadays that “great innovations” are trumpeted by heads of Academia in the full glare of media publicity. They desperately try to draw the attention of industrial or state sponsors to their money-starved institutions and thus ensure their survival. How many times we observed that such breakthroughs then quietly, or sometimes not so quietly, peter out? Formerly, the first and main criterion for funding a piece of work was its scientific merit and how well it is done rather than its perceived or supposed merit or usefulness for the public good. Science therefore is now highly directed, driven by tasks and products. Society must realize that it can build on good science but is led astray when fools itself with empty promises of progress not backed up by well-founded science. “The road to hell is paved with the best intentions”, and if one’s intentions are not even the best, then one gets to hell very quickly.

PRESSURE ON SCIENCE; THE INDUSTRIAL-POLITICÍAL COMPLEX

In the last twenty years most governments have invested a large slice of their money and pension funds in the fast developing and apparently financially promising genetic engineering technology and its products. Thus, governments are not disinterested bystanders in the debate whether GE technology is safe or not, rather the opposite. In fact, most of the time they strongly support the GE biotechnology industry. One of the best examples is the British Government that despite the rejection of GE foods by the great majority of the British people undemocratically ignores this in all its actions. Anyone voicing doubts over the safety of GE foods in public soon will find out that how far the establishment would go to try to destroy him/her even when the doubts are based on the results of sound experimental work. Messages of doubt are obviously uncomfortable to the scientific/political establishment with vested interests in the success of the GE technology (Royal Society, 1998). They do not tolerate even scepticism. For them this is almost like a religious crusade. The establishment must crush anyone who appears to be standing in their way and will even consider threats against those individuals whom they consider as influential sceptics (Flynn and Gillard, 1999). If this happened 500 years ago, the perpetrator would have probably been put to the stake and burnt. Nowadays the equivalent is to destroy the sceptical scientist, both as a person and definitely as a scientist.

The scientific establishment is not willing to concede that there are points that need to be clarified, which could only be done by further independent research. We are told that there is no difference between GE- and conventional foods and therefore there is no need to commission new research. For example it is said: genetic engineering, taking a gene from any donor organism and splicing it into another is just the same but faster and more precise than conventional breeding in which the offspring only has a mix of parental genes. It is perfectly well known that this is not true. One can argue whether genetic modification is better or worse, but it is certainly different. Again it is said: we eat tons of cauliflower mosaic virus (CaMV) during our lifetime, it is therefore inconceivable that using the DNA part of this virus in the genetic engineering vector construct, the CaMV *35s* promoter, as a molecular switch to turn on the transferred gene in the genome of the plant should present any safety problems in GE foods. However, these people know perfectly well what we normally eat is the full virus, which has a protein coat that covers the DNA. This is what our immune system recognizes. If you take off this coat, that determines the species specificity of the virus, it is a different matter again. It could be better or worse for safety, but it is different. Therefore the associated risks ought to be investigated. Likewise it is said: all DNA is degraded in the gut, when they know perfectly well that a small proportion of it does not break down, as documented in publications (see papers by Doerfler and Schubbert and his associates). This intact DNA should be of great concern to us and the associated risks ought to have been investigated. The top scientific establishment ignores these differences and uncertainties, perhaps because they are reluctant to fund research to investigate them even though we have methods to do so. So why don't we?

It is even more serious that in some instances prominent scientists are not just economical with the truth, but in fact they are lying. All the same they manage to force their views through by the considerable power of their prestige. This not only distorts science, but it is also taking the debate in a wrong direction. At issue is not only whether GM food is good or bad, but whether the scientific debate is conducted in an ethical manner. This is what we were used to in science before industry became the paymaster. We can all make mistakes, but the deliberate ones are far more serious than any sensationalist article that newspapers may write about scientific issues on GE foods. This is not the proper way to conduct serious scientific debate about the safety of GE foods as it is done today when the proponents and sceptics are not even willing to sit in the same room let alone properly debate the issues. It is possible that if the present rather Stone Age technology of genetic modification based on an outdated dogma of genetic determinism will be replaced by a more specific and less risky genetic technology, if such can be found, and if after transparent and critical examination its products are found safe by independent scientists, this will be a good thing for humanity. All the same, the emphasis must be on the words critical and independent. Even if such new and predictable gene splicing methods can be established the safety of the products must still be properly tested.

In those few instances when independent scientists investigated the problems and uncertainties in the products of GE technology, potentially serious problems surfaced. (e.g. see the article in the Lancet by Ewen and Pusztai, 1999 and comments by the Lancet Editor, Richard Horton).We don't know whether these problems can occur generally, whether they are irreversible and whether they have any pathological significance as we have very few data on the safety of GM foods. Our database is extremely narrow and limited (see Pusztai and Bardocz, 2006). One of the basic rules in experimental science is that if you want to challenge existing data or concepts, the only way is to do more experiments even though this is certainly made difficult by the industry’s reluctance to provide *bona fide* samples to independent researchers. But if this is not done the lack of evidence cannot be taken to support the point of view that GM food poses no health risk, particularly if very few attempts have been made to study the problem (Krebs, 2000). Indeed, in such cases it can also be said with equal justification that the converse claim is true: *i.e*. that there is no meaningful evidence of safety. When top scientists claim the safety of GE foods on such unsatisfactory grounds one always has this uneasy feeling that they may have some political agenda.

CORRUPTION OF SCIENCE AND SCIENTISTS

Apart from the possible harmful effects of the products of the GE technology on health and the environment the involvement of the industrial-political complex as paymasters of scientific research has a disastrous effect on science itself. The GE-biotech companies jealously guard the results of their research as not to give competitors an advantage and declare virtually everything as confidential business information (CBI). This prevents the exchange of results, views and opinions between scientists, the lifeline of science, without which no scientific progress is possible. Even more importantly, industrial funding of research leads to the corruption of values and even the scientists themselves. A PEER and Union of Concerned Scientist survey called this as a disinformation syndrome that afflicts government scientists. In a survey it was found that one in five of the scientists questioned had been directed to exclude or alter information in a scientific document. In another published survey (Wadman, 2005) more than 15% of the 3247 respondents said that commercial interests through political intervention directed them to change the design, methodology or reverse or withdraw research conclusions and 1.5% admitted falsification of data and/or plagiarism. Overall, about a third admitted to at least one of the ten most serious offences. In another survey by the Institute of Professionals, Managers and Specialists: 30% of the 500 respondents said they had been asked to tailor their research conclusions. These included 17% to change the results to suit the customer’s preferred outcome, 10% to change their conclusions if they wanted a further contract, 3% were told not to publish “unwelcome” results. In a survey of US Fish and Wildlife Service concerning the protection of endangered plants and animals the respondents reported that 44% have been directed to withhold data that indicated the need for protection of species, 20% have been instructed to compromise their scientific integrity by excluding or altering data and opinions and 56% knew of cases where commercial interests induced the reversal or withdrawal of decisions or conclusions through political intervention In an investigation of 103 government scientists by the N.I.H it was found that 44 violated ethics rules on collaborating with pharmaceutical companies, and 9 may have violated criminal laws. Many world-famous scientists, including Sir Richard Doll, have now been found out to have received substantial financial payments from relevant industries whose products they investigated but when the results were published failed to disclose financial ties to the company (Hardell et al 2006). Department of Health and Human Services received 274 complaints of alleged misconduct in 2004. Due to staffing shortage they could only investigate 23 of these. How can one blame society for no longer trusting the scientist? In the last century publicly funded scientists working on food safety were regarded as public watchdogs. It was always acknowledged that they acted in the interest of society and not of any industrial/commercial groups. To repair and restore the previous high standing in society of the scientists will take a long time and will only occur if there is a change in our attitude to science and its financing. When the realization will set in that if society wants independent scientists whom they can trust again they will have to restore the independence of science from its present subservient role to industry by funding independent research from the public purse.

SOCIO-ETHICAL ASPECTS OF SCIENCE

I have been invited to lecture at a number of liberal arts colleges in the USA in the past and was very favourably impressed by their curriculum in which a major emphasis was placed on trying to get the students to understand that in our democratic system whatever is done in science it will always have an effect on society. Every development always occurs in a social context. All students are required to understand this. Thus, courses in government science and ecology and so on are compulsory for all students, the intention being is that they must absorb this basic philosophy. Even students whose primary education is in science are made to see that their scientific activities will be done in a social context.

Some people voice the opinion, quite rightly, that the direction of scientific research should be influenced not only by scientists but also by the public who can bring different perspectives and values. Although in life our opinions are formed by all our life experiences, a great deal of these comes from our own professional life. Unfortunately for many people, life- and professional experiences seem to be running on separate lines. Though many scientists vow never to be involved with any biological research project that has obvious warfare implications or that the results of his research could be used against people, this is not so easy when the likely consequences of a project are not clear-cut. Even with strong ethical commitments, one does not always anticipate what are the potential outcomes, implications and consequences of their work. One of the consequences of today’s industrial sponsorship of science that the individual scientist hired for a particular job has very little free time to think about the social consequences of his work and deviate from the job he is doing. If one is successful in obtaining large chunks of money from industry to finance one’s work there are enough problems to keep up with the research and no time is left to contemplate the consequences. So if anything is not very obvious at the beginning, one doesn't start to question its implications.

The classic definition of science says that its aim ought to be to find out the truth about the world and us without any financial benefits or other advantages to the scientist himself. Unfortunately for most of us, this has been twisted out of its original meaning. Nowadays researchers are told that science must not be pursued just to please the scientific mind. It's not the truth that is important, but the truth for a particular social context. However, the government and the scientific establishment set the context because they have a pre-conceived idea what is good for us all, *i.e*. to change the world to suit our perceived interests regardless of the cost to others. In the present conditions academic freedom, the pursuit of truth is an illusion. One is usually told what one must do and find even though this agenda is anathema to science. If one knew in advance all the things that one was to find, there would not be much point of doing it! Sceptics are branded as Luddites, who want to stop "progress".

SOCIAL CONSENT

A scientist ought to consider the reality that he is not only a scientist but also a member of the public who wants to eat safe food and live in a clean environment. However, he must also recognize that other people in the community have the same rights and his actions must not jeopardise that. Ethical and social considerations must unavoidably come into scientific issues, both for the individual scientist and also for the scientific-political establishment. The scientist may think that he must have an absolute right to do anything, but he has no such right. For example, we have the means or may be able to develop the means for carrying out human cloning and even though it is reprehensible for the majority of scientists, some will attempt to do it. These claim that interference with this curtails their academic freedom. However, in reality projects like human cloning question and jeopardise all our basic moral values and they also unsettle the foundations of the whole structure of society and human existence. Also, nobody has the right to subject people to the results of their work without securing their consent. Thus, we have no justification to do experiments in which there is a human involvement without them consenting to this. The classic case is the USA where the FDA (Food and Drug Administration) does not allow GE foods to be labeled using the excuse that they are substantially equivalent to non-engineered foods and therefore if one is safe the other also must be. It is a fundamental human right to be able to exercise one's choice. However, without labelling this is denied to the American public. Moreover, even if some people consent to such experiments on themselves, a responsible scientist should draw the line. If he thinks that there is the possibility of harm coming to the consenting individual he should not experiment on the volunteer. The scientist should have a strong enough ethical stance to self-regulate his research activities whose results might jeopardise the long-term future of the human race. However, if scientists cannot draw this line, then others in society must do it for them because scientists are sometimes too close to the aims of their research project to be able to make rational long-term decisions that take the whole human race into consideration. They, for example must not be allowed to do experiments with human eugenics. Indeed, western nations fought a world war to stop this.

Science, particularly biological sciences must have a strong involvement with the public. Although obviously 7.5 billion people cannot be sitting around a table to discuss these issues, we shall have to find the best ways to involve people in discussing issues which may affect them. There has also to be involvement from other sciences, liberal arts, social sciences, environmentalists, philosophers, and representatives of various faiths, etc.- people who may legitimately hold different viewpoints. And such a debate must be done beforehand, not just after a technology has been developed, particularly with the GE technology now whose effects on the world are unpredictable and largely irreversible. The damage might have already been done before we could find out what possible harms can occur

In conclusion: Fundamental changes in the direction and financing of biological- and particularly genetic research have brought our civilization to a turning point. With the introduction of primitive irreversible genetic techniques in a dangerous combination with a product-and profit-orientated mind-set forced on society by a powerful political-industrial complex humanity faces an uncertain future. In the first time in our history we have created a self-reproducing biological system that we cannot control and whose consequences are uncertain, unpredictable and potentially dangerous. This is our unfair legacy to our children. Should it prove dangerous they will have to face the consequences of our action and it is unlikely that they will be able to reverse it.

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