From the test tube to the table

Public perception of GM crops and how to overcome the public mistrust of biotechnology in food production • *by Robert Marchant*

The first commercial exploitation of genetic technologies in the 1980s sparked a continuing debate over their acceptability, ethics and implications for society. Since this time, cloning, genetic screening and gene therapy have become topics of an intense discussion about how to use the potential of biotechnology in the best interests of the public, while criticism and outrage are mostly directed against genet-

generally endorsing the development of GM crops, the British House of Lords indicating that the benefits of GM crops outweighed any potential risks (House of Lords, 1999) and The Princess Royal expressing support for GM crops. But 'No danger from GM crops!' obviously does not make a good headline and negative coverage of GM crops continues to predominate. In the midst of media hype

phenomenon: perceived risk = hazard + outrage. The greater the perceived risk, the more people demand risk reduction and insist on stringent regulation to achieve zero risk. But the public often does not realise that zero risk is impossible to achieve and that policies consistent with a zero risk philosophy come at a great cost which is unnecessary to maintain environmental and consumer welfare.

For GM crops, the perceived risk is high because of the high level of outrage, and, in ignoring outrage, scientists tend to underestimate perceived risk. In order to communicate the actual risk to the public, it is therefore necessary to understand and focus on the outrage factor, which is partly a function of negative press campaigning by environmental groups and a lack of knowledge. Another reason is a general mistrust of scientists, which is based on the scientists' unwillingness to disclose and discuss the implications of their research in public.

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ically modified crops in the food supply. While GM crops are popular with growers and producers, the public is becoming increasingly uneasy about their potential environmental and health risks. Opposition started initially in Europe, particularly in the UK, but as a result of various environmental and consumer health scare stories in the media, there is now also growing disquiet among consumers in the USA and Asia.

Lurid accounts of 'Frankenfood', vandalising of field trials of GM crops and retailers withdrawing GM foods from their shelves are the consequence. A number of scientific publications have been exploited by anti-GM lobbyists to support the notion that GM crops pose a risk to health and the environment (Table I). Although this served to highlight potential risks or drawbacks of GM crops, there were equally newsworthy events about positive aspects that failed to make it to the front pages of the press. These included the creation of the so-called 'Golden Rice' to combat Vitamin A deficiency (Ye *et al.*, 2000), Oxfam acknowledging that GM crops could be of benefit to farmers in developing countries, the Nuffield Council on Bioethics in the UK

about the so-called 'GM crisis' the average citizen finds it difficult to obtain credible information to decide whether GM foods are safe or unsafe.

Scientists involved in the debate about GM technologies often feel frustrated that the public ignores scientific facts and bases its opinions on illogical assumptions, such as those presented by some anti-GM lobbyists. But it is critical to

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understand that there often is a void between the actual or statistical risk that can be verified scientifically and the risk that is perceived by the public. Scientists depend on risk assessments, based on scientific evidence and statistical data, in which risk is defined as magnitude—how bad the problem could potentially be—multiplied by probability—how likely it is to happen. In contrast, the public's method of evaluating the risks of new technologies or harmful products is a cognitive process. Sandman (1994) developed the following formula to explain this

measure the extent of perceived risk of GM crops and the reasons for this. The last Eurobarometer Survey of more than 16,000 people from 16 nations (INRA-ECOSA, 2000) showed that perception of risk was greater for biotechnology in food production than for many other areas of biotechnology. While the perceived risks of GM crops remain high, it is unlikely that there will be increased acceptance of this technology. Though the actual risk from a GM product is immutable, the level of public acceptability could change when the benefits appear to outweigh the

Table I. Anatomy of the GM crisis in the UK

April 1998	Several biotechnology companies are fined for breaching crop spacing regulations intended to reduce gene escape
March 1998	Delta Pine and Land Co., USA, are granted a patent for 'Terminator Technology'. Supermarket chain Iceland announces that its own-brand products will be GM-free
May 1998	The UK's leading grower of organic food seeks a court order to prevent his organic crops being 'contaminated' by an adjacent GM field trial—the claim is unsuccessful and an order to remove the crop is not granted
June 1998	Prince Charles calls for a ban on GM foods, suggesting that scientists were straying into 'the realms that belong to God and God alone'. Protesters damage a number of field trails throughout the UK over a period of several weeks. Monsanto undertakes a £1 million advertising campaign in the UK to promote the benefits of GM crops.
August 1998	Professor Arpad Puztai appears on TV suggesting that rats had damaged immune systems after feeding on GM potatoes containing a snowdrop lectin transgene—Puztai is subsequently suspended. An audit report later clears him of fraud but suggests that his findings were not supported by the data.
December 1998	Prince Charles launches a GM forum on his official web-site
February 1999	UK Labour party revealed to be receiving funding from biotechnology companies. Major food retailer Marks & Spencer halts use of GM ingredients in its food products. Several newspapers begin campaigns against GM foods.
March 1999	Sainsbury's supermarkets, (which originally stocked the first GM tomato puree) stop using GM products in its own-brand foods
May 1999	Christian Aid produces report opposing the use of GM crops in developing countries. Reports that <i>Bt</i> maize could harm Monarch Butterflies in USA.
May 2000	Prince Charles again attacks scientists, GM crops and GM foods during a Reith lecture. Accidental cultivation of GM plants across Europe following contamination of batches of non-GM seeds.

perceived risk, thus reducing the level of outrage. Scientists and regulators should therefore strive to communicate the benefits of GM crops as well as the nature and outcomes of risk assessments. This will be critical not only for current GM crops but also for future applications of GM technology.

Inc., 1999), conducted in eight countries, showed that 79% of those surveyed had read or heard about GM foods. This figure rose to over 90% in the UK and Germany and was lowest in the USA (66%) and Brazil (39%). These results appear to be related to the level of press coverage of the GM crop debate.

same survey suggested that food safety/health concerns had the greatest perceived risk (31%), while a reduction in food quality was of least concern (4%).

A further problem is that high levels of awareness do not necessarily reflect a better knowledge about a topic (Hoban, 1998). In Europe, awareness of problems related to GM crops is high (Angus Reid Group Inc., 1999), but knowledge of the science behind it is relatively poor. The 2000 Eurobarometer Survey showed that 35% of respondents believed that 'ordinary tomatoes do not contain genes, while genetically modified tomatoes do'. Of those questioned, 24% believed the statement 'if a person eats a GM fruit, their genes could be modified as a result'. Other surveys in the USA and Japan show that provision of factual information

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As the debate over GM crops and products has intensified, many scientists have become involved in increasing the public understanding of genetic manipulation. These initiatives are based on a 'deficit model', which assumes that if the public knew more about GM science, it would be more supportive of the technology. Those involved in public understanding initiatives should be aware of the current level of knowledge, and assess how the public understanding relates to the acceptance of GM technology. In fact, recent surveys suggest that, while awareness of GM foods is high, the public understanding of biotechnology is low. The Angus Reid Poll (Angus Reid Group

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improves food quality (15%) and leads to a reduction in pesticides (15%). 10% of respondents said they were unsure of any benefit from GM foods, while 25% believed there were no advantages. The

indeed increases consumer acceptance (Hoban, 1998). Although the strength of the relationship between acceptance and understanding remains unclear, the survey data make a compelling case for

educating the public about the science so that they better understand the nature of genetic modification as well as the methods of scientific risk assessment. However, those who aim to increase

about the problems arising from conventional breeding that makes it difficult for the consumer to weigh the risks and benefits of conventional versus new methods. For instance, the public is often

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public acceptance of GM crops and products are unlikely to do so solely through increasing public understanding.

The context in which information is supplied and received, as well as the source of this information, is as likely to determine public reaction as the information itself. Indeed, credibility and trust in information sources play a major role in how consumers react to novel products (Frewer *et al.*, 1995). Of those polled in the 2000 Eurobarometer Survey, 26% said that they mainly trust consumer protection organisations, the medical profession (24%) and environmental organisations (14%). Other information sources received only low scores in this evaluation: universities (7%), the media (4%) and political parties (0%). However, in light of previous misguided safety reassurances from scientists and politicians about thalidomide, beef/BSE and nuclear power, it is not surprising that trust in scientific and governmental sources has declined. Less than half (45%) of the respondents in the 2000 Eurobarometer Survey felt that their governments are regulating biotechnology well enough, compared to 29% who felt the opposite and 26% who were unsure. Those seen as stakeholders in GM technology, including scientists who are believed to be influenced by corporate research funding, are not seen as providers of accurate information (Pollara and Earncliffe Research, 1999). It is therefore vital that scientists and regulators retain their independence and objectivity in relation to GM technologies, and that such objectivity is conspicuous to society in general.

While the lack of knowledge and public trust in scientists or regulators is more or less the same for all applications of GM technologies, it is particularly damaging for GM crops; in contrast to biomedical research, GM crops are not seen as having direct benefits for consumers. Furthermore, there is a lack of knowledge

unaware of the extensive safety tests GM crops are subject to in contrast to the lax testing of traditionally bred crops. It is crucial that those involved in public education convey not only the health, nutritional and environmental benefits of using GM technology in crop and food production to the public, but also present the potential problems that may exist with more traditional methods.

Furthermore, scientists, regulatory agencies and the public need to become engaged in a discussion about the methods for assessing and weighing the risks of new technologies. While scientists can generate the necessary information, it is up to individuals and society to select the

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level of risk they are prepared to accept and what regulatory processes are needed to minimise risks. Scientists must acknowledge the social contexts affecting risk perception and that public opinion must be taken into account. To overcome public mistrust, it is critical that the regulatory process is transparent and open, and that there is maximum public participation at all stages.

For GM food, this means that labelling will be one of the most critical factors influencing public acceptance. Some believe that there is no need for labelling as there is no evidence suggesting that GM food is different from a conventional product (Caulder, 1998). But consumers in the EU place immense value on their freedom to choose whether to consume GM products or not, and perceive a greater risk if they are involuntarily exposed to a GM product. Failure to label GM products is therefore likely to

reinforce the belief that there is something to hide. Effective labelling could also convey the benefits of a GM product, which may help to increase consumer acceptance.

As long as public understanding of GM technology remains relatively low, opposition to GM crops is likely to remain high. Thus, increasing the public understanding of the science behind GM technology is critical in raising levels of consumer acceptance. But consumers will only be able to make informed choices about GM crops and products if they have a better understanding of the technology. The challenge for scientists now is to move from a 'deficit model' towards an 'engagement model', in which all interested parties can debate the social impact of scientific advancement. This can only be achieved by increasing public understanding of the benefits of GM technology, by increasing the understanding of methods of risk assessment and management, by securing consumer choice and by employing effective, transparent regulation in which the consumer is acknowledged to be a major stakeholder.

References

- Angus Reid Group Inc. (1999) International awareness and perceptions of genetically modified foods. The Economist/Angus Reid Poll. <http://www.angusreid.com>
- Angus Reid Group Inc. (2000) Significant knowledge gap in debate over modified foods. <http://www.angusreid.com>
- Caulder, J. (1998) Agricultural biotechnology and public perceptions. *AgBioForum* 1, Summer 1998, pp 38–39. <http://www.agbioforum.org>
- Frewer, L., Howard, C. and Shepherd, R. (1995) Genetic engineering and food: What determines consumer acceptance? *Brit. Food J.*, **97**, 31–36.
- Hoban, T.J. (1998) Trends in consumer attitudes about agricultural biotechnology. *AgBioForum* 1, Summer 1998, pp 3–7. <http://agbioforum.org>
- House of Lords (1999) Select Committee on the European Communities 2nd Report. EC Regulation of Genetic Modification in Agriculture. <http://www.parliament.the-stationery-office.co.uk>
- INRA-ECOSA (2000) The Europeans and Biotechnology: Eurobarometer 52.1. Directorate General for Research. Directorate B—Quality of Life and Management of Living Resources. <http://europa.eu.int/comm/research/pdf/eurobarometer-en.pdf>
- Pollara and Earncliffe Research (1999) Majority immune to biotech health scare: willing to take risks. by Kathryn May, July 24, 2000, National Post, USA.

Sandman, P.M. (1994) Mass media and environmental risk: Seven principles: RISK; Health, Safety and Environment, Summer, pp 151–260.

Ye, X., Al-Babili, S., Kloti, A., Zhang, J., Lucca, P., Beyer, P. and Potrykus, P. (2000) Engineering the provitamin A (β -carotene) biosynthetic pathway into (carotenoid-free) rice endosperm. *Science*, **287**, 303–305.

Robert Marchant is a researcher in plant genetic manipulation at the University of Nottingham, UK

and Chair of the Nottingham Branch of the British Association for the Advancement of Science. He has a special interest in science communication and the public understanding of science and has been involved in a number of initiatives to increase the public understanding of science.

This article is written in a personal capacity.
E-mail: robert.marchant@nottingham.ac.uk

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Cleaning up behind us

The potential of genetically modified bacteria to break down toxic pollutants in the environment • by *Víctor de Lorenzo*

These days the terms genome and genomics elicit an instant association with the human genome and the potential benefits for human health that might be squeezed out of it. This is a bit surprising for a microbiologist. Of course, we humans will be the main beneficiaries but what is the actual significance of the human genome in the general context of the biosphere? For instance, in terms of enzymatic diversity, our DNA barely contains enough information to use just a few of the carbon sources that occur in nature. There is no way that we can resist abrupt

Many bacteria cope with life with only 1% of the number of genes that a human cell carries within its nucleus. But such a limited amount of genetic information is exploited in the most refined manner, encoding all imaginable devices that are needed at the molecular, physiological and cellular levels to survive and proliferate. Bacteria are particularly good at consuming an amazingly large variety of chemicals as carbon and energy sources. They also employ a large assortment of inorganic compounds as final electron acceptors, making our oxygen-based

prokaryotic host. Furthermore, exposure of bacteria to a wide variety of chemical compounds created the selective pressure necessary for the evolution of novel catabolic enzymes capable of degrading or modifying these compounds. Millions of years of brutal selective pressure have created catalysts that perform reactions with an efficiency and specificity that organic chemists can only dream of. Indeed, mono- and di-oxygenation of aromatic rings—the initial steps in most metabolic pathways for degradation of hydrocarbons by soil bacteria—are still formidable challenges for chemical engineers. Other pathways and enzymes evolved to degrade quite recalcitrant compounds, such as polycyclic aromatic hydrocarbons. Evolution has generated a wide diversity of bacteria with metabolic enzymes and pathways optimised for breaking down many unpalatable, yet natural, chemicals.

But modern chemistry has released into the environment large amounts of compounds that had never been present in the biosphere in significant amounts. Urban

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environmental changes or brusque physico-chemical challenges—let alone nutrient starvation, exposure to heavy metals, lack of oxygen or high/low pressure—with this limited metabolic outfit. How can we deal with the increasingly evident deterioration of the environment brought upon us by our very own actions? It is time to recognise that the main—perhaps the only—chance of counteracting the devastating consequences of our activities on the environment lies in the largely unexplored genetic pool of the microbial world.

Bacteria are the most successful life forms on this planet, being able to colonise the most extreme and diverse biotopes.

respiration chain look embarrassingly simple.

Since bacteria have been around for at least 3 billion years—2 billion years longer than eukaryotic cells—they have had ample time to develop numerous mechanisms with which to draw energy

Millions of years of brutal selective pressure have generated bacteria with metabolic enzymes and pathways to break down many unpalatable chemicals

from the environment. We have every reason to believe that virtually every molecular mechanism that supports life was first tested for its performance in a

and industrial activities have mobilised otherwise inactive chemical species—typically hydrocarbons, heavy metals or organic compounds with heteroatoms.