



SENSE ABOUT SCIENCE
MAKING SENSE OF GM

What is the genetic modification of plants
and why are scientists doing it?

With thanks to...

...the working group:



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Introduction: UK research institute directors on why we need public clarity about GM

Policy makers and journalists in Europe are sure that we will be discussing GM again in the next year, mainly because of international worries about growing enough affordable food as well as the use of land to grow crops for fuel. GM is now a mature and widely applied technology. The diverse advocacy and media coverage of GM over the past five years, however, has created a very unclear picture of what GM is and does; and what scientists and agriculturalists are trying to achieve.

Crop improvement, whether by GM or conventional breeding, is just one component of a wider social and economic debate about agriculture, food and the environment. But unless there is better understanding and well-informed discussion about GM, it will be impossible for the public and policy makers to judge what crop technologies can contribute to food security and natural resource and climate change management; and it will be even harder for the research scientists in our institutes to increase our knowledge and deliver on the urgent demands of agriculture.

Prof Ian Crute,
Director, Rothamsted Research

Prof Peter Gregory,
Director, Scottish Crop Research Institute

Prof Chris Lamb,
Director, John Innes Centre

Prof Patricia Nuttall,
Director, Centre for Ecology & Hydrology

Prof David White,
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JIC Photography

Introducing this guide

There have been more Google searches on GM crops in the past two years in the UK than anywhere else in the world.¹ With over a trillion GM meals consumed and nearly 120 million hectares of GM crops grown outside of Europe, it's perhaps not surprising that people have questions about why that is, what GM is, what it does, where GM crops are grown, whether they are eating them and what would happen if they did.

We have found it difficult to point people towards anything that could give them a direct way into the debate without being overwhelmed by scientific detail on the one hand or polemic on the other. Faced with a likely resurgence of the GM issue, we went in search of straightforward answers. We found that much of the commentary is written as though we all know what GM is and does - but then often gets it wrong, talking about "zombie seeds" and "super weeds". It has sometimes been difficult to find clear answers to questions such as "are we eating the products of GM in the UK?" and "was 'terminator technology' ever used?"

There are some big gaps between perception and reality. For example, conventional plant breeding already exploits crosses between plants that would not occur in nature or induces random mutations artificially with radiation or chemical agents, so it isn't really more "natural" than GM. "Eating genes" is something that everyone does every day, whether they eat GM foods or not. GM crops are grown in 23 countries, so the world isn't and can't be "GM-free". Discussion about GM also seems to have become a proxy for other much-needed discussions about food shortages, economic power of multinational corporations, food safety, farming systems and trade agreements, which go far beyond this technology and its applications.

This guide is about what scientists are doing and why. We have asked a lot of people to help, from researchers at the main UK plant research institutes to farmers, toxicologists and people who could lay their hands on relevant material. The contributors helped define the most useful material to include from a scientific point of view (we've included some individual quotes too) and Sense About Science has done its usual thing of trying these out with civic and community groups to find the most valuable and counterintuitive contributions. Arriving at just 20 pages was tough², but here it is; we hope it helps you to cut through what you hear and to distinguish fact from misinformation.

Ellen Raphael
Sense About Science

Prof Jonathan Jones
The Sainsbury Laboratory, John Innes Centre

1. Google Trends 26 January 2008

2. This is a guide to gaps in general discussion. Don't stop here if you want an overview of research: go to the back section and www.senseaboutscience.org.

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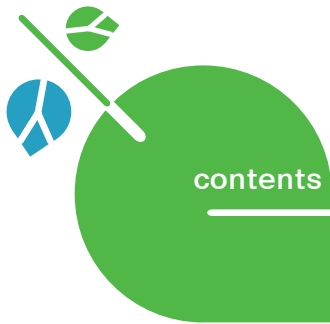
There Goes the Science Bit... a hunt
for evidence



"I've got nothing to lose by trying it":
a guide to weighing up claims about
cures and treatments



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01 **Interfering with nature** page
08

GM is a development in a long line of plant breeding techniques. Older techniques shuffled the plant's genes, leading to lots of unintended changes, whereas GM is more precise. It is relatively new (though over 20 years old) but many of the comments that it is "unnatural" are just as true of plants bred for conventional and organic agriculture.

02 **Why GM?** page
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GM is one of several new and improving techniques in plant breeding, alongside a range of molecular techniques such as marker assisted selection. As a technique that is faster, not so hit and miss, and able to deliver genetic changes that would never occur through conventional methods, GM is uniquely useful, although not the solution to everything.

03 **"Releasing" GM organisms** page
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GM crops are grown in 23 countries on 114 million hectares and research trials are underway on six continents. The early regulations on growing GM crops were instigated by scientists doing the research. Contrary to the headlines, "super weeds" aren't super; they are plants that can tolerate a particular weed-killer (herbicide). They occur in conventional agriculture and, like other problems such as wildlife diversity and gene flow, are a function of farming methods rather than GM.

04 **Eating GM foods** page
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Foods from GM plants are not necessarily different from foods produced from plants or animals that have been developed using older methods of selective breeding. It depends on what the breeding aimed to change. There are many products containing GM in the global food chain, including throughout Europe.

05 **GM and world crop production** page
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A lot of discussion about GM crops has been about whether or not they solve world hunger, which isn't a useful discussion because GM is a plant breeding method, not a social or economic system. Large companies supply most of the world seed markets for the few GM varieties that are grown; they supply most of the world seed markets for conventional and organic agriculture too. The intensifying regulatory framework means it is costly to have a variety approved; this has damaged the research into locally-important crops, which is usually undertaken in the public sector and by small partnerships in poorer countries.



01. Interfering with nature

GM is a development in a long line of plant breeding techniques. It is different, as discussed below, but the idea that it is “unnatural” is equally true of plants bred for conventional and organic agriculture.

All plant breeding and crop cultivation manipulates natural phenomena and all plant breeding, from the seeds people use to grow tomatoes in their gardens to the global production of wheat, has involved genetic changes.

Since the start of crop cultivation, farmers and plant breeders have looked for desirable traits (characteristics), such as plants that are shorter and less easily destroyed by wind, to incorporate them into future generations. Originally, they created new plants by cross-breeding. This shuffled the plant's genes, leading to lots of unpredictable variation, and better variants were selected. In contrast, GM involves defining the desired characteristic, and putting in a gene that confers it.

Genetic modification: reaching the parts other plant breeding methods can't reach.

Advances in molecular biology in the 1970s made it possible to identify the specific gene responsible for a trait, isolate and transfer it, from any type of organism, to plant cells. Instead of making tens of thousands of genetic changes, with GM you insert a gene with a known single beneficial trait into the plant. You know what the protein specified by the gene does, so it is a more targeted change with less unintentional disruption to the plant's other genes. Plant breeders embraced GM because it offered this precision and a quicker way of obtaining a desired trait in a plant.

Genetic modification sounds strange, but if you were presented with news headlines about other processes of plant breeding, they could sound equally strange. For example, at the start of the 20th century, with the discovery that x-rays caused mutations in fruit flies and barley, plant breeders and geneticists began using radiation to force genetic changes (mutagenesis). This increased variation in the specimens that grew, thus increasing the chances of finding a suitable one to breed from. It was very successful: 1,916 crop and



legume³ varieties were released worldwide⁴; much of the UK's beer was produced using a mutant variety of barley called Golden Promise. However, achieving a new trait was still a lengthy and unpredictable process, even with help from mutagens, because thousands of crosses might result in only one or two useful new varieties.

Gene transfer is not where all plant science is leading. There are other technologies in use in which genetic material is altered but which do not involve *transferring* genes (transgenics). Breeders select from all the tools at their disposal. Whether they choose a GM approach depends on which trait they want to incorporate into new plant varieties and on whether older techniques can accomplish that.

Word on words: GM stands for genetic modification or genetically modified. It usually refers to the moving of genes between species and varieties using a technique called 'gene splicing', although all methods of breeding modify and exchange genes. Organisms bred using GM are referred to as GMOs – genetically modified organisms. Gene splicing is just one of the new methods available to investigate life at the molecular level, which are sometimes referred to under the general term 'biotechnology'.

“Not a great deal of DNA is being added to the organism compared with the amount already there. Living organisms can have over 50,000 genes but this is often only a fraction of the DNA they have. The insertion of a gene may increase the amount of DNA in a cell by 1/1,000,000th or less. The inserted gene is intended to have a marked effect but is not altering the biology of the organism to a great extent.”

Dr Philip Taylor, Molecular Biologist and Arable Farmer

“GM crop plants look and behave in most respects like conventional crop plants: they differ only in very specific ways. When anti-GM protestors tried to stop a trial that included GM peas at the John Innes Centre in Norwich they actually destroyed a collection of non-GM peas from around the world that looked very different from conventional UK peas – they assumed that these must be GM. The GM peas – which looked identical to conventional UK peas – were left undamaged.”

Prof Alison Smith, Head of Department of Metabolic Biology, John Innes Centre

Crossing boundaries

Some people have said they're concerned that GM crosses species boundaries. It isn't a new thing to transfer traits between species. Hybridisation has been achieved across what were once thought to be 'breeding boundaries': commonly eaten varieties of rice, maize, oats, pumpkin and currants (among others) are the result of such wide crosses. However, GM makes possible genetic changes, including between animals and plants, which would be highly unlikely or never occur using mutagenesis or other conventional techniques.

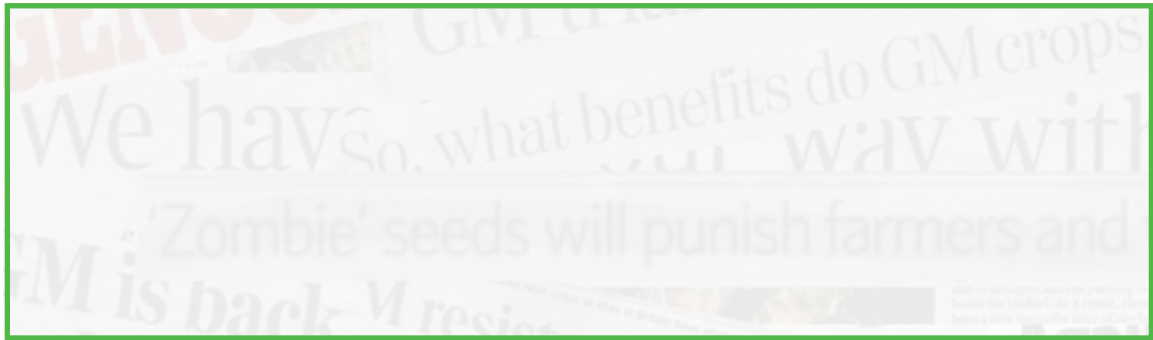
“A gene is a piece of information which can be used in many different organisms, just as a word can have the same meaning in many contexts. All living organisms are related to one another and share the same fundamental system of genetics so a gene from one organism may well work satisfactorily in another. You could put a gene from a fish into a fruit – or a fruit gene into a fish: fish genes are simply pieces of information and do not carry a label saying 'I come from a fish'.”

Prof Vivian Moses, Biochemist and Microbiologist

3. Legumes are fruits that develop in a pod, such as peas, beans and peanuts.

4. Batista et al (2008). Microarray analyses reveal that plant mutagenesis may induce more transcriptomic changes than transgene insertion. *PNAS* 105, 9:3645.





02. Why GM?

There are old and new challenges that GM, along with other developing molecular techniques, could address. So where is GM especially or uniquely useful? GM is being used by researchers to try to produce plants that can:

- increase crop yields, particularly where this can maximise the plant's use of inputs such as fertiliser;
- reduce damage to crops after they are harvested, by identifying natural genetic defences against insect damage and fungal contamination in foodstuffs;
- make crops more tolerant of stresses (cold, drought, salt, heat), which are traits that can be introduced from other plants that exhibit them;
- improve the nutritional value of food in very specific ways without changing other features;
- reduce reliance on chemical pesticides by using genes that are available in, for example, soil micro-organisms;
- reduce the environmental impact of livestock farming, by introducing changes in clover and grass so that cattle eating them produce less methane;
- provide alternative resources for industrial use by using plants (and therefore sunlight as the source of energy) to produce starches, fuels and pharmaceuticals - things that they could never be conventionally bred to produce.

“Plant breeding has been very successful but it is an imprecise art. The new molecular technologies, involving both GM and marker assisted breeding (non GM) are changing this.”

Prof Chris Leaver, Emeritus Professor of Plant Science, Oxford University

What's in the pipeline?

Three types of GM plants are currently being used or researched. These are described as 'generations' of plants; it doesn't follow though that this represents their sequential development but more characterises how commercially successful they have been so far.

The first generation plants have traits that help farmers to manage their land or reduce costs; these are the GM crops widely planted throughout the world (see Section 3). They can grow without being damaged by insect attack (e.g. maize and cotton), or are tolerant of a particular weed killer (e.g. maize, cotton, soybean, oilseed rape), or both.

The second generation has traits that enhance the nutritional value of food and animal feed (including maize and soya with increased levels of amino acids or improved oil composition for animal feed to reduce the need for dietary supplements) and drought tolerance traits.

Golden Rice

Vitamin A deficiency (VAD) causes blindness in around half a million people, mainly children, every year.⁵ Half of them die within 12 months of going blind and others die of diseases like malaria because VAD severely affects the immune system. It is prevalent in poor communities that rely on rice as their major food because their diets don't contain the beta-carotene that the body needs to convert to vitamin A.

GM technology has been used to create a variety called Golden Rice, which produces beta-carotene because it has genes from maize and from a soil bacterium. It has been created with joint public sector and commercial funding and the final product will be given to national governments to distribute to resource-poor farmers free of charge.

Golden Rice is not intended to provide all of the recommended daily amount of vitamin A, but to help

exceed the threshold of malnutrition to overcome VAD. Some early versions of Golden Rice drew criticism from anti-GM campaigners, who said that people would need to consume "12 times more rice than normal to satisfy the minimum daily adult requirements of Vitamin A."⁶ The criticisms concerned a prototype of Golden Rice, modified with a gene from daffodils, which was not as good as the current version of Golden Rice now being field tested prior to release. This contains a gene from maize and has 23 times more beta-carotene than before.⁷

Applications for field trials for Golden Rice have been delayed by the regulatory process, which was designed with large companies rather than small humanitarian projects in mind. The delays have frustrated the researchers on this project but they now hope that Golden Rice and similar beta-carotene enhanced crops such as GM sorghum and sweet potato will soon be contributing to overcoming VAD.

Work on the third generation of GM crops is looking at how plants might be used as factories to make pharmaceutical products and renewable industrial compounds. Research is underway, for example, to produce edible vaccines within plants as a way of facilitating access to vaccines in countries where the distribution or refrigeration of medicines is poor.

5. Nutrition health topics: Micronutrient deficiencies, Vitamin A deficiency. World Health Organisation.

<http://www.who.int/nutrition/topics/vad/en/index.html>.

(Visited on 3 Feb 09).

6. Golden Rice: All glitter, no gold. Greenpeace News, 16 March 2005.

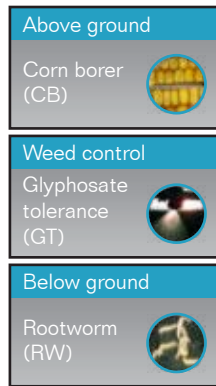
www.greenpeace.org/international/news/failures-of-golden-rice.

(Visited on 3 Feb 09).

7. Paine et al (2005). Improving the nutritional value of Golden Rice through increased pro-vitamin A content. *Nature Biotechnology* 23, 4:482.

Research into the next GM crops for commercial use is focused on putting several agronomic traits in one plant. For example:

Stacked GM traits in maize



Source: C Leaver

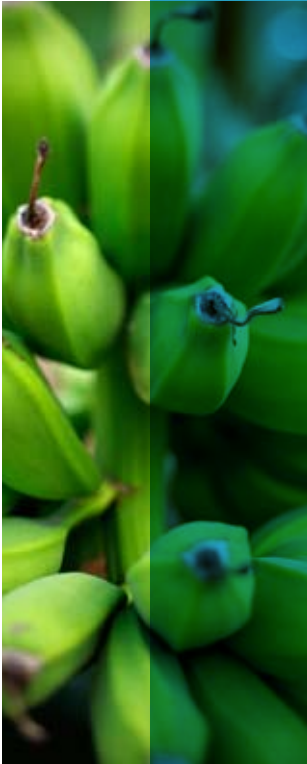
Bramley Apples in Kent

Genetic modification of fruit crops has been used by East Malling Research since 1985 to complement conventional breeding programmes. GM is another tool for plant breeders to improve the performance of commercial plants. Sometimes, improvements to a fruit cannot be achieved by conventional breeding but can be addressed by GM.

Fruit growing in Kent is part of the cultural heritage, but new technologies are needed to improve the competitiveness of locally grown varieties such as the Queen Cox and Bramley. A sought-after target for these varieties is extended storage life, which would allow them to be more available in winter months, reduce imports, reduce use of chemicals in storage, help alleviate superficial scald and improve texture (ensuring the future of the industry in the case of Bramleys).

Bramley apples are an ideal candidate for GM as their pollen is sterile (and therefore unable to cross-pollinate), so you can't use conventional methods to induce variation.

By Prof David James, Emeritus Fellow at East Malling Research



Banana losses to Black Sigatoka fungus in Uganda

Black Sigatoka is a fungus that causes a leaf spot disease in banana plants and reduces the yield of the plant by 50% or more. The disease was first seen in Fiji 50 years ago but has now spread worldwide. It attacks dessert varieties such as Cavendish, East African Highland bananas (EAHB) and plantains alike. The prevalence of the disease in countries such as Uganda, which depends on bananas and other plantains as a staple crop, is a major threat to food security. Over the years, the fungus has developed resistance to many fungicides so that, for effective control, more applications of more chemicals at higher strengths are needed and, not counting the health and environmental issues, this can cost in excess of \$1000 per hectare, well beyond the reach of the African smallholder. In the long term, conventional cross-breeding programmes may produce varieties with improved resistance. However, for today's Ugandan farmer GM is the only rapid route to a resistant EAHB variety and, for the commercial producer, GM is the only route to a Black Sigatoka-resistant Cavendish.

The bananas we eat are sterile and have no seeds. To produce new plants, suckers are taken from around the base of an existing plant and transplanted. When these take root, they produce identical plants with identical fruit. Botanists

believe that 10,000 years ago naturally occurring hybrids gave rise to edible but sterile varieties that were cloned by early farmers in south-east Asia. Reproducing them asexually means that, for example, all Cavendish are identical to the plant brought to the Caribbean 100 years ago.

An EAHB Ugandan sweet banana has been transformed with genes that should confer resistance to both Black Sigatoka and bacterial wilt. GM plants were imported into Uganda in 2007 and are now being field tested. The results will take 5-10 years to come out, but the hope is that after the field trials, the best banana lines will be multiplied and that NARO, the Ugandan public agricultural institution, will provide the technology to Africa.

By Prof Mike Gale, Plant Geneticist



Mike Gale



03. “Releasing” GM organisms

GM research and plant trials are ongoing in Africa, Asia, Australasia, Europe, North and South America. Some GM plants are in glass houses, some in open-air trials and some in field trials for regulatory approval (i.e. observing them in agricultural practice). Crops with two GM-derived traits – resistance to weed killer and making their own insecticidal protein - are grown commercially in 23 countries on 14.3 million hectares⁸, though only GM maize has so far been commercially licensed to be grown in Europe. Some commentators talk about “releasing” or “freezing” GM as though it is a one-off decision yet to be taken; actually it has been going on gradually through research and regulatory approval over more than 20 years.

Controlling GM

The initial work in making a GM plant takes place in the laboratory and glasshouse. This is controlled to ensure that no parts of the plant (e.g. the pollen or seed) spread outside a contained area. When a suitable plant has been selected, it is grown in confined field plots to test whether its new trait works outside laboratory conditions and is stable. Researchers assess any potential effect on the environment, such as the plant cross-breeding with wild relatives, and potential for weediness or damage to friendly insects.

Both non-commercial and commercial growing of GM plants in the UK requires permission from the Secretary of State for Agriculture’s department, though commercial growing requires more tests and agreement with other EU Member States. Once these authorities are satisfied with the results of testing for food, feed and environmental safety compared to similar conventional crops, the product can be given “general release status”. There are few constraints on conventional breeding, except on the rare occasions when it results in a completely new crop when it is also assessed under the regulations on novel crops and food.

History of GM regulation

The original regulations on growing GM crops were instigated by scientists doing molecular biology research. The first published GM experiment was a paper in 1972 describing the insertion of bacteriophage genes into an animal virus DNA. It led scientists to raise questions about potential risks to human health⁹ and to organise the Asilomar Conference in 1975, attended by scientists, lawyers and government officials to discuss the technology. They concluded that experiments could proceed under strict guidelines drawn up by the US National Institutes of Health.

8. James (2007). Global Status of Commercialized Biotech/GM Crops. *ISAAA Briefs* 37.

9. Jackson et al (1972). Biochemical method for inserting new genetic information into DNA of Simian virus 40: circular SV40 DNA molecules containing Lambda phage genes and galactose operon of *Escherichia coli*. *PNAS* 60:2004.



There are now international biosafety regulations.¹⁰ The UK has its own regulations, in line with EU directives.¹¹ Unlike other regulations, which are *reactive* to a risk being shown, the biosafety laws operate *proactively*, anticipating possible risks.¹² You might get the impression that this shows GM to be dangerous but it's rather the product of how the regulations developed to allay concerns.

Selling and producing seeds

Companies can only sell seeds if they are on the National List, which is managed by DEFRA, or in the EU common catalogue (once a seed has been approved for use by one European member state it goes into the catalogue). For a new plant variety to be added to a National List, whether it is GM or not, it must show through field trials that it passes the **DUS** tests. It must be:

Distinct from other varieties,

Uniform and

Stable in its genetic make-up from year to year.

Agricultural crops also have to demonstrate satisfactory value for cultivation and use.

Most agricultural crops, apart from vegetables, are grown from certified seeds. To reach the required standard and maintain purity, there are contracts between farmers and seed companies setting out strict separation distances in the field, defined in UK law by the UK Seeds Regulations. This applies to *all* crops, not just GM.

In the EU, as well as using certified seed (which guarantee crop purity), farmers can save seeds from their own commercial crops. When using farm-saved seed, they pay an agreed royalty fee to the plant breeder who owns the intellectual property in these seeds. Farmers don't save seed from hybrid crops, as the next generation of crops grown would not meet the DUS requirements: hybrids are not uniform and stable because they 'breakdown' in each subsequent generation, as home gardeners who try regrowing white lupins from collected seeds often discover.

"Super weeds"

Illegal GM crop that could spawn superweed, Daily Mail 20 December 2008

GM super-weed threat, Birmingham Post 28 November 2002

GM trials spawn the super-weed, Daily Mail 26 July 2005

Plant raises fears of a GM super weed, Daily Telegraph 26 July 2005

Newspapers have enjoyed headlines about cross-pollination between herbicide-resistant GM plants and their wild or weedy relatives leading to "super weeds". However, "super weeds" aren't particularly super; they are plants that can tolerate a particular herbicide. They already occur in conventional agriculture and are destroyed with a different herbicide or better crop rotation, although multiple tolerance could become an important issue for the farmer if chemical and crop rotation are not adhered to.

-
10. Including: World Trade Organization; World Health Organization; Food and Agriculture Organization Codex Alimentarius (food safety), Cartagena Protocol of the Convention on Biodiversity.
 11. The regulations are: Environmental Directive (2001/8), the Novel Food Regulation (258/97), Genetically Modified Food and Feed Regulation (1829/2003) and Traceability and Labelling Regulation (1830/2003).
 12. Kinderlerer (2000). Genetically modified organisms: a European scientist's view. *N. Y. U. Environmental Law Journal* 8:556.

David Hill, Arable Farmer: *"We have been dealing with weeds becoming resistant to herbicides for years, particularly black grass in the wheat crop. Wheat grown continually or in short rotation relies on herbicides for the control of weeds. Black grass can become resistant very quickly so it is vital to vary the active ingredient in the weed killer and rotate the crops grown on each field to stop this happening. There will be the same need in biotech crops."*

Gene flow

Gene flow sounds like a new problem but it's not. With some crops, GM or not, genes are transmitted to similar crops or wild relatives through pollen carried on the wind or by insects. The discussion about GM highlighted the wider risk of gene flow from crops that have been altered deliberately and from plants that have evolved tolerance, particularly in countries where species originate.

In 2000, amid requests that GM crops should be kept separate, two UK research councils (the BBSRC and NERC¹³) launched a collaborative review of the likelihood of gene transfer from plants and the potential outcomes of such 'gene flow'. In 2005, they reported that separation distances between crops restrict gene flow and that gene transfer from GM plants to soil bacteria is "vanishingly small and highly unlikely".¹⁴ The review also examined crosses between conventionally-bred oilseed rape and its wild relative; it was found that around 32,000 hybrids are produced every year in the UK. However, the hybrids were not 'healthy' plants and very few went on to produce a second generation.

With both gene flow and "super weeds", the problem is one of farm management and arises when farmers don't rotate their crops or switch herbicides. GM might help with 'no till' farming (sowing the seed directly into the ground without ploughing, so reducing damage to the soil structure), which allows for better crop rotation.

GM crops and wildlife diversity

Loss of wildlife diversity on farm land is also not a problem specific to GM but of agriculture in general; the losses of habitat, use of fertilisers and pesticides, and changes in crop rotations have all reduced the numbers of plants, insects and birds in Britain¹⁵. Research into how GM maize crops influence non-target insects (those they aren't intended to kill) in the environment found that whether the maize is GM or not has much less of an impact than how much insecticide is used.¹⁶

Lots of stories have circulated about GM crops affecting diversity. Scientists and regulators have been monitoring and investigating potential risks from particular GM crops. Their main concern was that herbicide-resistant crops would require the use of more powerful herbicides, reducing still further the weeds that are important food for many insects and birds in the UK.

13. Biological Sciences Research Council, Natural Environment Research Council.

14. BBSRC and NERC (2005). Briefing: a better understanding of gene flow.

15. Krebs et al (1999). The second silent spring? *Nature* 400:611.

16. Other factors affecting monarchs. Agriculture Research Service. www.ars.usda.gov/sites/monarch/sect3_2.html. (Visited on 3 Feb 09).



Monarch butterflies and Bt maize

GM pollen 'can kill butterflies',
BBC News 20 May 1999

Pollen from GM maize
shown to kill butterflies
The Guardian
20 May 1999

This question was addressed by the **Farm Scale Evaluations**, the largest and most rigorously audited experiment of its type. It looked at the effects of herbicide-resistant oilseed rape, sugar beet and maize on farm wildlife on over 200 fields across the UK. The main results were published in 2003¹⁷: differences in the amount and range of weeds and insects between GM and the conventional crops were found, with GM oilseed rape and sugar beet showing fewer of both and maize showing more. HOWEVER, none of the results occurred because the crops had been developed by genetic modification, as some comments suggested, but because these particular crops gave farmers new options for weed control. They used different herbicides, with different effects. Moreover, differences in biodiversity between the sugar beet, oilseed rape and maize trials were greater than those between GM and conventional varieties of each crop.

“The results reflect the effects of overall crop management practices rather than of genetic modification per se; similar evaluations of non-GM changes in cropping would very likely have found greater or similar impacts.” **Prof Les Firbank, Ecologist and Head of North Wyke Research**

Honey bees and GM

“There has been speculation that a decline in honey bees is due to GM crops¹⁸. However, bee populations are declining just as fast in Europe, where GM is not grown, as anywhere else. Possible causes under investigation include varroa mites and insecticides.”
Dr Alan Dewar, Entomologist

Bt maize is a GM corn that produces the Bt (*Bacillus thuringiensis*) insecticidal protein so that it doesn't have to be sprayed. Controversy about the impact of GM on wildlife began with a story about this maize after a study published in 1999 suggested that it harmed Monarch butterflies.¹⁹

The researchers had found in laboratory tests that the butterfly larvae were damaged when they ate milkweed leaves heavily sprinkled with Bt maize pollen. This wasn't completely unexpected as the Bt protein used in the maize is known to kill moth and butterfly caterpillars. The 1999 study was done in Petri dishes and used much higher amounts of pollen than are found on milkweed leaves at the edges of cornfields. In 2000 and 2001, three studies²⁰ showed that under natural conditions the butterfly larvae are not exposed to Bt pollen in such large amounts. In 2002, the US Agriculture Research Service published the results of a two-year study on whether Bt maize posed a threat to Monarch butterflies and concluded that it didn't²¹. For there to be a threat, there had to be at least 1000 grains of pollen per cm² of leaf; in fields in Nebraska, Maryland and Ontario, average density was 170 grains inside the fields, with the maximum outside the fields 79 grains (maize pollen is quite heavy so it doesn't spread far). Bt176 maize, one of the first Bt corns, was found to be harmful at lower densities than 1000 per cm². It had not been planted widely and was phased out in 2003.

These differing results underline the need to monitor crops and to test them in the correct environment.

17. The Farm Scale Evaluations of spring-sown genetically modified crops. Papers of a Theme Issue. *Philosophical Transactions of the Royal Society (B)* 358:1773 (2003).

18. The GM honey trap; Frankenstein threat to bees. *The Mirror*, 19 August 1999; Are GM crops killing bees? *Der Spiegel*, 22 March 2007.

19. Losey et al (1999). Transgenic pollen harms monarch larvae. *Nature* 399:214.

20. Sears et al (2000). Preliminary report on the ecological impact of Bt corn pollen on populations of non-target Lepidoptera, including the monarch butterfly, in Ontario. Canadian Food Inspection Agency, Plant Biotechnology Office.

21. Hellmich (2001). Monarch larvae sensitivity to *Bacillus thuringiensis* - purified proteins and pollen. *PNAS* 98, 21:11925.







04. Eating GM foods

Foods from GM plants are not necessarily different from foods produced from plants that have been developed using older methods of selection and breeding. It depends on what the breeding aimed to do. There are a lot of products from GM crops in the food chain, although European manufacturers and retailers don't mention it. It is estimated that 90% of some animal feed is derived from GM because it is cheaper and more plentiful than conventional feeds.

Some consumers have expressed concerns about 'eating genes' and 'eating DNA' in foods from GM sources. All food contains genes and DNA but this is digested and disposed of in the usual way: *"When we eat any food, we are eating the genes and breaking down the DNA present in the food."*²²

 *"About 1% of the dry weight of all fruits, vegetables and meats is DNA (i.e. genes)."*
Prof Michael Wilson, Emeritus Professor in Plant Virology

 *"We have been consuming genes since we evolved and there is no evidence that they can enter human cells from the food we eat."* **Prof Alan Malcolm, Chief Executive Institute of Biology**

In the US, foods containing GM ingredients have been eaten for over a decade. It is estimated that more than 80% of processed foods on their supermarket shelves contain them and over a trillion meals containing GM ingredients have been consumed without revealing any adverse health effects.

A review of research on animals fed on GM by the European Food Safety Authority (EFSA) concluded: "a large number of experimental studies with livestock have shown that recombinant DNA fragments or proteins derived from GM plants have not been detected in tissues, fluids or edible products of farm animals like broilers, cattle, pigs or quails."²³

Although there is no evidence that these foods have caused harm, national authorities follow guidelines to assess the safety of new GM foods case by case. The GM version of the food is compared to one made from conventional crops and checked to see whether there is a nutritional difference between the two or a heightened risk of allergy or toxicity.

The Flavr Savr[®] tomato was the first commercialised GM crop and went on sale in 1994 in the US. It contained a trait that suppressed early ripening to give the tomato improved quality and flavour. In the UK, a concentrated tomato paste using GM tomatoes went on sale in 1996. This sold well until supermarkets, following campaigns by anti-GM protestors and media, withdrew the product in 1999.

22. GM food. Food Standards Agency.

www.eatwell.gov.uk/healthissues/factsbehindissues/gmfood
(Visited 3 Feb 09).

23. Statement on the fate of recombinant DNA or proteins in meat, milk and eggs from animals fed with GM feed. European Food Safety Authority 19 July 2007. www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178623095798.htm (Visited on 3 Feb 09).





Despite the fact that GM foods are rigorously assessed and regulated, stories disputing their safety still circulate. One of the most enduring started in August 1998 when nutrition researcher Dr Arpad Pusztai claimed on the television programme *World in Action* that rats fed on GM potatoes (genetically modified to include snowdrop lectin, which is poisonous to insects) had suffered serious damage to their immune systems and shown stunted growth. The next day, newspaper headlines claimed 'immune system damage in tests' and extrapolated to claims about the effects these potatoes, and other GM plants, might have on people.

It was not made clear that the research was very experimental, or that the potatoes were not being developed as a food crop but were being used to see if the inclusion of lectin made them insect-resistant. When the research was published at a later date²⁴, no evidence of stunted growth or damage to the immune system was substantiated. The Royal Society reviewed the data and concluded the study "is flawed in many aspects of design, execution and analysis and that no conclusion should be drawn from it."²⁵

GM foods and allergy research

Some researchers hope that one day it will be possible to reduce allergens in foods using GM. The work is at an early stage of trying to reduce the allergenic properties of a protein without changing its function. At the moment, researchers know quite a lot about the genetic characteristics of allergenic foods but less about the genetic differences between people that may predispose them to have allergies.

24. Ewen et al (1999). Effect of diets containing genetically modified potatoes expressing *Galanthus nivalis* lectin on rat small intestine.

The Lancet 354:1353.

25. The Royal Society (1999). Review of data on possible toxicity of potatoes.



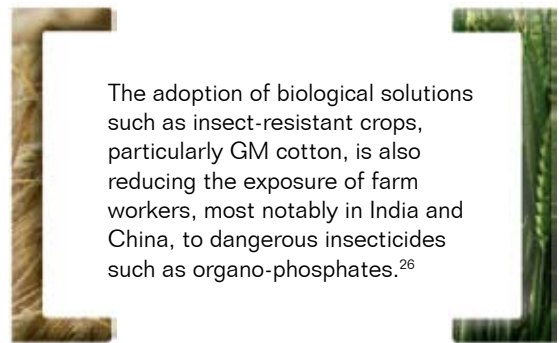
05. GM and world crop production

A lot of discussion about GM crops has been about whether or not they solve world hunger, which isn't a useful discussion because GM is a plant breeding technique, not a social or economic system. It does, though, need to be considered in the context of world food production. Although the 'Green Revolution' in cereal production in the 1960s tripled the world food supply, the population has grown from about 3 billion in 1960 to 6.72 billion in 2008. The increased yields of the 1960s were partly due to new crop varieties, and partly to the use of agrochemicals (fertilisers and pesticides) and improved irrigation.

“We could feed everyone on the planet today as a result of successful plant breeding and modern agriculture but making sure that everyone has enough to eat is more about politics than science.”

Prof Chris Leaver, Emeritus Professor of Plant Science, Oxford University

With this growing population there is more demand for land, water and energy. It has been estimated that as much as 50% of the world's arable land may be unusable by 2050 because of salt build-up after too much irrigation, over-grazing or desertification. Plant scientists are seeking ways to increase yield from available arable land and, through plants tolerant to environmental stresses and pests, from land that couldn't otherwise be used. With the agrochemical solutions of the 1960s reaching their limits, scientists are looking to biological solutions such as GM, mutagenesis and marker assisted breeding.



“GM cotton is grown widely throughout China. In 2008, under pressure to produce enough food for its growing population, China committed \$3.5 billion to a research and development initiative on GM crops for food and feed.” **Prof Jonathan Jones, Plant Scientist**

“The amount of agricultural land available to feed each person recently dipped below 0.3 of a hectare for the first time in history. Food-producing land is increasingly subject to flooding and drought, even in the UK. The big issue is how we produce food for a growing population **and** reduce farming's environmental impact.”
Dr Helen Ferrier, Chief Science and Regulatory Affairs Adviser, National Farmers Union

26. James (2002). Preview: global status of commercialized transgenic crops. *ISAAA Briefs* 27.
Bennett et al (2006). An application of Life-Cycle Assessment for environmental planning and management: the potential environmental and human health impacts of growing genetically-modified herbicide-tolerant sugar beet. *Journal of Environmental Planning and Management* 49, 1:59.



Multinational companies and supply of GM

Large companies supply much of the world seed markets for the few GM varieties that are grown; but they supply much of the world seed markets for conventional agriculture too. The regulatory framework around GM has now become so complex and stringent, particularly in Europe, that to license a variety takes a long time (on average three years longer than conventional crops) and therefore a lot of money. This kind of investment encourages companies to protect their returns vigorously. It certainly discourages public-good plant breeding initiatives and small partnerships, leaving more research to the commercial sector. It has damaged orphan crop research and work undertaken by small partnerships in poorer countries.

Public-good plant breeding

“Orphan” crops include tef, finger millet, yam, roots and tubers. They are important in particular regions but are not traded around the world; as a result the private sector has no interest in them.²⁷ Without public-good plant breeding initiatives there is a serious risk that the needs of farmers in developing countries find little space in international plant breeding research.



JJC Photography

11 *“No-one wants to see large multinational companies ruthlessly exploiting poor farmers. Scientists are not naïve and are aware that multinationals’ interests are financial rather than humanitarian BUT to refuse GM technology on that basis is throwing the baby out with the bathwater. There are many publicly funded GM schemes that have humanitarian, not financial, aims.” Dr Philip Taylor, Molecular Biologist and Arable Farmer*

Terminator Technology

Genetic Use Restriction Technology (GURT) is a proposed method for restricting the use of GM plants by causing second generation seeds to be sterile. In the late 1990s, GURTs, nicknamed ‘terminator’ technology, were conceived by companies to protect their commercial interests and intellectual property rights in GM crops. This was seen as a violation of the rights of farmers to grow crops from saved seeds. A global moratorium on the testing and commercialization of the technology was established under the United Nations Convention on Biodiversity in 2000. It was reviewed in 2006 and still stands.


Environmental concerns about the cross-pollination of GM crops have led to renewed interest in using GURTS so that any resulting seed would be sterile, but at present the technology is not used or ready for use. The European research programme, Transcontainer, is looking at other technologies that might prevent cross-pollination.

It wasn’t made clear in previous discussions about GURTS that in conventional agriculture farmers buy new seeds every year as standard practice, and are usually tied to a supplier for each season’s seeds. Popular F1 hybrids are also single use because the plant characteristics aren’t reliably repeated the following year. Farmers in developing countries use this system where they can, as it guarantees quality, although many still use home-saved seed and choose varieties that enable them to do that.

27. Nuffield Council on Bioethics (2003). The use of genetically modified crops in developing countries: a follow-up discussion paper.



While the incentive for companies is to produce seeds that farmers want, there are potential benefits for consumers. When crops need fewer inputs and are easier to manage, food is produced more efficiently and at lower cost, which means cheaper food on the shelves. Protecting plants from disease and pest attack also results in higher quality and safer food.

 *“Much of the discussion in the public arena has ignored all issues of cost. This is partly because food now represents a much smaller proportion of a weekly budget than it did 40 years ago. But shop in a supermarket in any less affluent area, and you see people having to put things back on the shelf because they find they don’t have enough money. The recent increases in food prices have only accentuated a problem that is already there in our society, but little talked about.”*

Prof Derek Burke, Emeritus Professor of Biological Sciences

It surprises some people to find that much GM research is not only carried out by companies, but also at public research institutes and plant science departments in universities. In developing countries, in particular, public sector laboratories rather than commercial companies are often the source of GM products for local use. In the UK, the main publicly funded plant research centres are the John Innes Centre, Rothamsted Research and the Scottish Crop Research Institute. A lot of related research on GM and the environment is conducted at the Centre for Ecology and Hydrology and on GM and food at the Institute for Food Research.

Internationally, there are several organisations that help to transfer the technology and knowledge gained by developed countries into crop sciences. One is the **International Service for the Acquisition of Agri-biotech Applications (ISAAA)**, a not-for-profit organisation; another is the **Consultative Group on International Agricultural Research (CGIAR)** which supports 15 agricultural research centres including the **International Rice Research Institute (IRRI)** and the **International Maize and Wheat Improvement Center (CIMMYT)**.

 *“Most citizens do not conform to the anti-GM stereotype, as usually portrayed. The majority, in the middle ground, are confused and heavily influenced by the most recent media coverage, but open to be influenced by new information and opportunities as they emerge.”*
Professor Joyce Tait, Scientific Adviser, ESRC Innogen Centre

“Looking at the history, the new demands and the scientific challenges that have been laid out for this document, it’s striking that as a global society we are asking a huge amount from plant research, from finding bigger yields in shrinking environments to addressing multiple-resistance to weed-control chemicals; and asking it to find solutions that work in less predictable climates and for more people. However, looking at how the public discussion has gone so far, very little of plant research and its uses, particularly the role GM methods might have, seems to have been covered. But while this has left many researchers frustrated about progress, particularly of public sector plant breeding, what’s also striking is that the projects that are underway and planned in UK institutes are still shaped with a far-sighted and creative energy. And the researchers are looking for an open and fresh public discussion of that work, why they’re doing it and what we are expecting them to achieve.”

Ellen Raphael, Sense About Science





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Useful resources:

On our website (www.senseaboutscience.org) you can find both scientific reviews and commentaries about GM, and links to institutes involved in related research.

In conjunction with this publication, the Institute of Biology is reprinting its factsheet specifically on questions about food: *Genetically Modified Food: All you ever wanted to know about GM foods but were afraid to ask*. It can be downloaded from www.iob.org.

The Food Standards Agency has published consumer information about GM foods on its website, www.food.gov.uk.

If you want to locate scientific papers and reviews, the best place to start is the UK's national academy of science, the Royal Society. It submitted several papers and scientific commentaries to the Government's GM Science Review Panel in 2003 (www.gmsciencedebate.org.uk). They are all available at: www.royalsociety.org.uk under Science Issues>GM plants.

The Nuffield Council on Bioethics published a discussion paper, *The use of genetically modified crops in developing countries* in 2007. It can be downloaded from www.nuffieldbioethics.org/go/ourwork/gmcrops/publication_313.html.


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