Environmental Science
FACT SHEET
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GENETIC ENGINEERING

Transgenic organisms
A transgenic organism is an animal or plant into which a gene from a different species has been inserted.

● ***Examples of transgenic animals:***

- Pharming: insertion of genes from humans into, for example, cows or sheep so that their milk contains useful drugs or vaccines. For, example, scientists have inserted a gene from humans into sheep which allows the sheep to produce relatively large quantities of a protein that is used to treat people with a fatal lung disease.

- Organ transplants: pigs are inserted with a human gene. It is hoped that such pigs will develop organs, for example a liver, that can be used for transplants in humans.

- A gene that helped pout (it's a fish!) tolerate cold ocean water has been transferred into salmon where it enables the salmon to grow three times faster, making production cheaper. The gene enables the salmon's hormone production genes to work all year round. Normally, the salmon's hormone production genes switch off when the water temperature falls below a certain level. By overriding the salmon's normal reaction to cold temperatures, the pout genes mean the salmon grow all year round.

● ***Examples of transgenic plants:***

- The gene coding for vitamin A production has been inserted into rice, significantly increasing the vitamin A content of that crop, so helping to prevent blindness.

- The gene giving tolerance of the herbicide glyphosate has been inserted into soybeans. This allows the soybean crops to be liberally sprayed with glyphosate. The glyphosate kills all the weeds which would otherwise have had to be killed by deep ploughing. The problem with deep ploughing is that it increases soil erosion. So, in this case, it is claimed that gene transfer has helped to promote soil conservation.

- A gene giving potatoes resistance to *Phytopthora infestans* – the fungus that caused the Irish potato famine – has been inserted into that crop from alfalfa.

- Some plants possess genes that mean they are able to grow in soils with very high aluminium concentrations. The gene means they are able to absorb the aluminium from the soil and store it in their biomass. These genes have now been transferred into fast growing plants that effectively clean up the soil. The plants can then be harvested and removed, leaving behind a soil that is now capable of growing useful crops.

Is GM natural?
Supporters of such genetically modified (GM) organisms have argued that GM technology shouldn't cause anyone any concerns because it is simply an extension of traditional selective breeding techniques that have been used for thousands of years (see Factsheet 001 Selective breeding of crops and animals). Some forms of GM are, but most aren't. In the course of evolution, related species of plants have crossed with each other and, in many cases, produced new species, capable of reproducing and producing viable offspring. But evolution has not produced plants that contain genes from fish or pigs that contain genes from humans.

Arguments against transgenics:

● ***Health problems***
- Transgenic plants may not be safe to eat or may cause adverse reactions. This is because genes code for proteins. By changing the code we may cause entirely new proteins to form that the human body cannot recognise. Such a protein could be toxic or it could trigger the body's immune reaction. In the US, 45 GM crops are on sale but there is no labelling to let the public know which foods contain GM and there is no monitoring programme to see if they are having any effects on health.

- Much research uses plants that contain marker genes* which confer antibiotic resistance. The British Medical Association (BMA) are worried that antibiotic resistant bacteria could infect other bacteria or humans through the food chain *(Fig. 1)*. They want a complete ban on the use of antibiotic resistance marker genes in GM foods because if GM results in bacteria gaining antibiotic resistance, the consequences for human health could be disastrous.

Fig. 1 The transfer of antiobiotic resistant bacteria.

GM maize contains a marker gene which gives resistance to the antibiotic ampicillin —*fed to*→ pig —*gene transfer*→ bacteria in pig gut —*meat containing antibiotic resistant bacteria*→ humans

***Marker genes:** In the exam you will not need to know anything about marker genes so the following brief explanation is for you Biologists out there. During GM we are trying to get cells to take up new genes. In practice, some cells do and some don't. We need to know which ones have and which ones haven't. This is done by using marker genes, which are attached to the new gene, and which are responsible for a characteristic that is easy to test for. Very often, genes that give resistance to a particular antibiotic are used as marker genes. Finding out which cells have taken up the new gene is then easy: you simply dose all of the cells in antibiotic and any that survive must have taken up the marker gene and, therefore, the new gene.*

Ethical problems

- Multinational companies are trying very hard to persuade developing countries to plant huge areas with their GM crops. These crops sometimes rely on large inputs of fertilisers which have to be imported from developed countries. There are fears also that GM crops will contain terminator genes – these prevent fertile seed being produced on the crop – thus forcing poor farmers to buy new seed every year from the multinational. Some people believe that making farmers dependent upon multinationals in developed countries in this way is ethically wrong.

- Is a potato plant that contains a gene from a fish still a plant? Or is it part-animal, part-plant? Some vegetarians do not want their food to contain genes derived from animals and people of Jewish and Muslim faith do not want their food to contain genes from pigs.

- It may be possible to produce designer pets - for example, domestic cats that have no hunting instinct. But is depriving an animal of a behavioural characteristic ethically acceptable?

- There can be significant animal suffering involved. The most common technique used in producing transgenic animals is to microinject the desired gene into the developing nucleus of an egg of the host animal. The injection of the DNA into the nucleus of the egg is a hit and miss affair. Sometimes, thousands of eggs have to be injected to get one successful take-up of the gene. Even if the gene does become inserted into the embryo, it often becomes inserted incorrectly, resulting in abnormal embryos or death of the embryo. The modified embryos are then transferred into a suitable host mother, in which the embryo develops normally through to birth.

Environmental concerns

- Much research is being directed towards developing herbicide-resistant crops. Most research has been on developing glyphosate resistance.The aim is to allow the farmer to be able to liberally apply the herbicide, confident that all of the weeds will be killed but that their crop will be unharmed. This may lead to increased use of herbicide and greater residues on food. In New Zealand, Monsanto has applied to the government for a 200-fold increase in allowable residues of glyphosate in soybeans.

- Pollen from genetically modified crops may be capable of fertilising the "wild" type plant or a close relative and, in time, this may lead to the extinction of the original genotype.

- If pollen from a herbicide-resistant GM plant pollinates a weed, that weed may then become resistant to the herbicide. There are fears that this could produce super-weeds. Herbicide-resistant oilseed rape has already hybridised with several wild relatives.

- Although there are an estimated 1 million people in Zambia who are starving, the Zambian government has banned the distribution of GM cereal, given as aid from Canada and the US, because it fears that this will contaminate domestic varieties, harming their ability to be exported. Similarly, in the UK, organic farmers consider GM crops as non-organic. They are worried that their crops could be fertilised by pollen from GM crops, contaminating them.

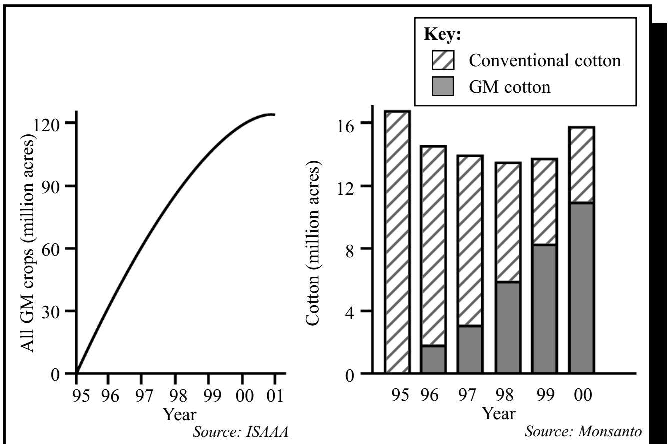
- Some GM crops have been made dependent upon large inputs of artificial fertilisers, thus problems from the manufacture and use of these may increase.

- Plants that are capable of producing their own insecticides may kill non-target species, some of which may be pollinators.

- Transgenic salmon may escape from their cages and reproduce, out-competing wild salmon for food and habitats. The GM salmon eat more food and grow much faster than the wild salmon. They might even reproduce with the wild salmon with unpredictable ecological effects. **Greenpeace** have lobbied aggressively for a total ban on the release of GM salmon into the wild, arguing that their release could lead to the extinction of wild salmon and permanently alter ocean ecology. "You can't pull the GM fish out of the ocean once they're in, and say you're doing a product recall."

- Loss of biodiversity – GM accelerates the trend whereby we rely on fewer and fewer types of crop. This means that our food supply is more vulnerable to climatic change or pest outbreaks. In the US, for example, Monsanto are demanding that farmers plant only GM patented seed and, world-wide, the area devoted to GM crops is expanding rapidly *(Fig. 3)*.

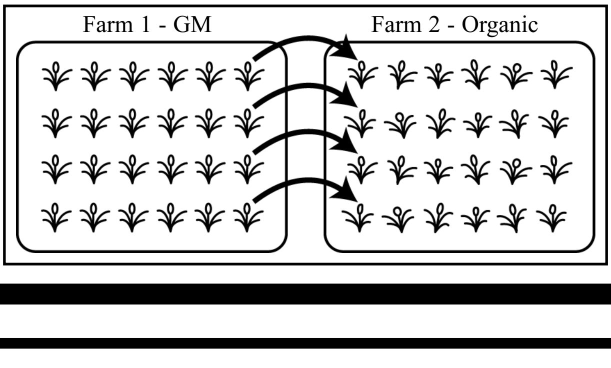
Fig. 3 Worldwide GM crop production.



Preventing the spread of pollen?

The spread of pollen from GM plants threatens to contaminate non–GM plants (Fig. 2).

Fig. 2 The spread of GM pollen.



- *Scientists left 10m gaps between GM and non-GM crops, thinking that this would be too far for the pollen to travel*

- *In New Zealand scientists have found GM pollen on crops 300km from the GM trial site. In this case the pollen is thought to have blown that distance but in the UK bees have been shown to carry pollen for 5km.*

- ***Friends of the Earth** believe that the UK should be completely GM-free, arguing that if GM crops are commercially planted, it is inevitable that non-GM crops will be contaminated.*

Table 1 GM crops - benefits v. problems.

Benefits	Problems
↑ pest resistance & ↑ growth rates ∴ ↑ food production ∴ ↓ starvation & ↓ food prices	↑ dependency of developing countries on developed countries and multinationals
↓ use of fertilisers and pesticides?	↑ use of fertilisers and pesticides?
↑ shelf life, ↑ nutritional content of food, ↑ medicinal benefits from food.	↓ biodiversity & use of traditional varieties ∴ ↓ genetic diversity ∴ ↑ susceptibility to pest epidemics

In terms of the environment, GM food is causing huge controversy:

- Its supporters believe that GM techniques will result in nutritious, high-yielding, disease–resistant varieties that may, in time, even be capable of fixing their own nitrogen. Malnutrition and starvation will decline, pesticide and fertiliser use will fall.

- Critics argue that there is already plenty of food and that people starve because of political problems that stop effective distribution. They see the development of GM as having only one purpose – to make multinationals rich.

Case study: Cotton

India has the largest cotton-growing area of any country in the world. Unfortunately, much of the cotton is destroyed by the cotton bollworm and the mean yield is 300kg per hectare – less than half the global mean. In an effort to reduce losses to this pest, the Indian government has given the go-ahead to plant huge areas with Monsanto's GM cotton. In China, 1.5m ha of land has already been planted with Monsanto's GM cotton. Monsanto's GM cotton contains a gene that allows it to produce a toxin that kills the bollworm (Fig. 4).

Fig. 4

Cotton is inserted with a gene from *Bacillus thuringiensis* (Bt) which allows the cotton to produce an insect toxin – a natural insecticide.

↓

Bollworm eats cotton

↓

Bollworm dies after ingesting the toxin

↙ ↘

Less need for farmers to use insecticide sprays. | Yield increases so profitability increases.

Problems

1. *Natural parasites of cotton bollworm, which normally help to control the population of the bollworm, are also killed by the toxin.*
2. *Insect species diversity has decreased in areas planted with the modified cotton.*
3. *Some scientists predict that the cotton bollworm will, over generations, develop resistance to the toxin, thus rendering the GM cotton useless.*
4. *Some scientists are worried that pollen from the genetically modified cotton could contaminate adjacent non-GM crops.*

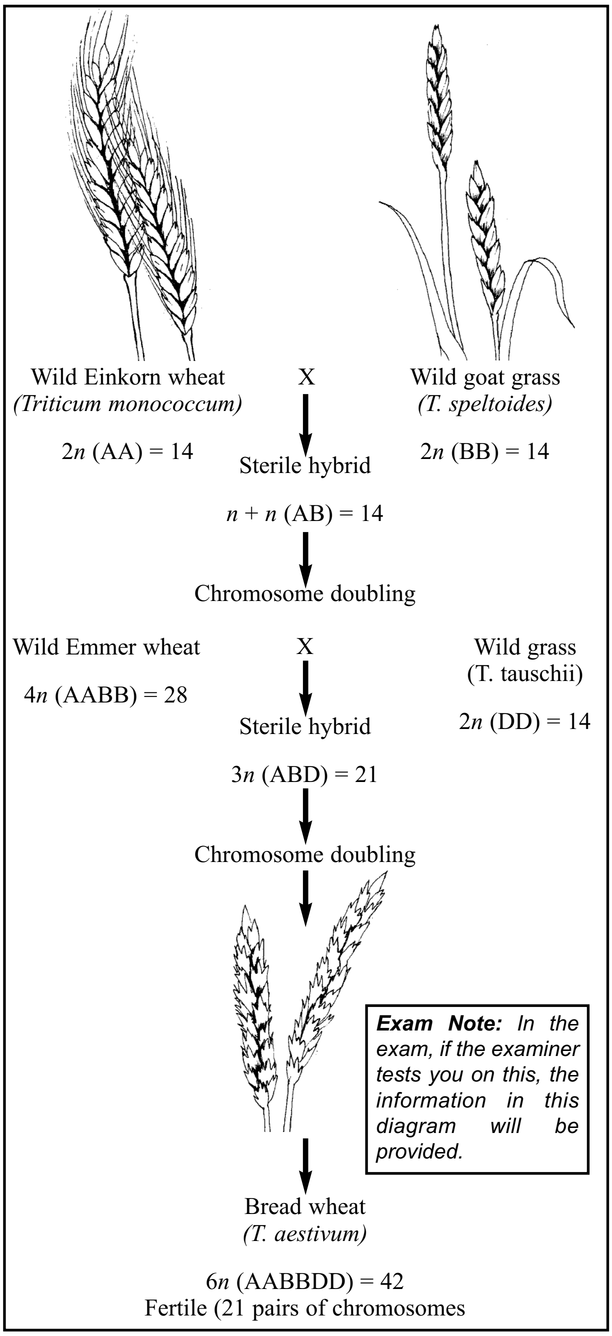
Polyploidy

Polyploids are individuals that contain multiples of the normal two sets of chromosomes. Normally every cell in an organism contains 2 sets of chromosomes – this is known as diploidy and has the notation 2x, where x refers to the number of sets of chromosomes. Triploids are therefore 3x, and tetraploids 4x etc.

Polyploidy occurs in 70% of angiosperms (flowering plants). Polyploids tend to have bigger cells, bigger seeds, greater disease resistance and grow faster than normal individuals. These characteristics may contribute to their success in adapting to hostile environments.

Sugar beet, bananas, watermelon and oysters all exhibit polyploidy and modern bread wheat, *Triticum aestivum*, is a hexaploid *(Fig. 5)*. Polyploidy can be induced in the cells of plants such as wheat and blackberries by treating them with cochicine, extracted from crocuses.

Fig. 5 Polyploidy in wheat.

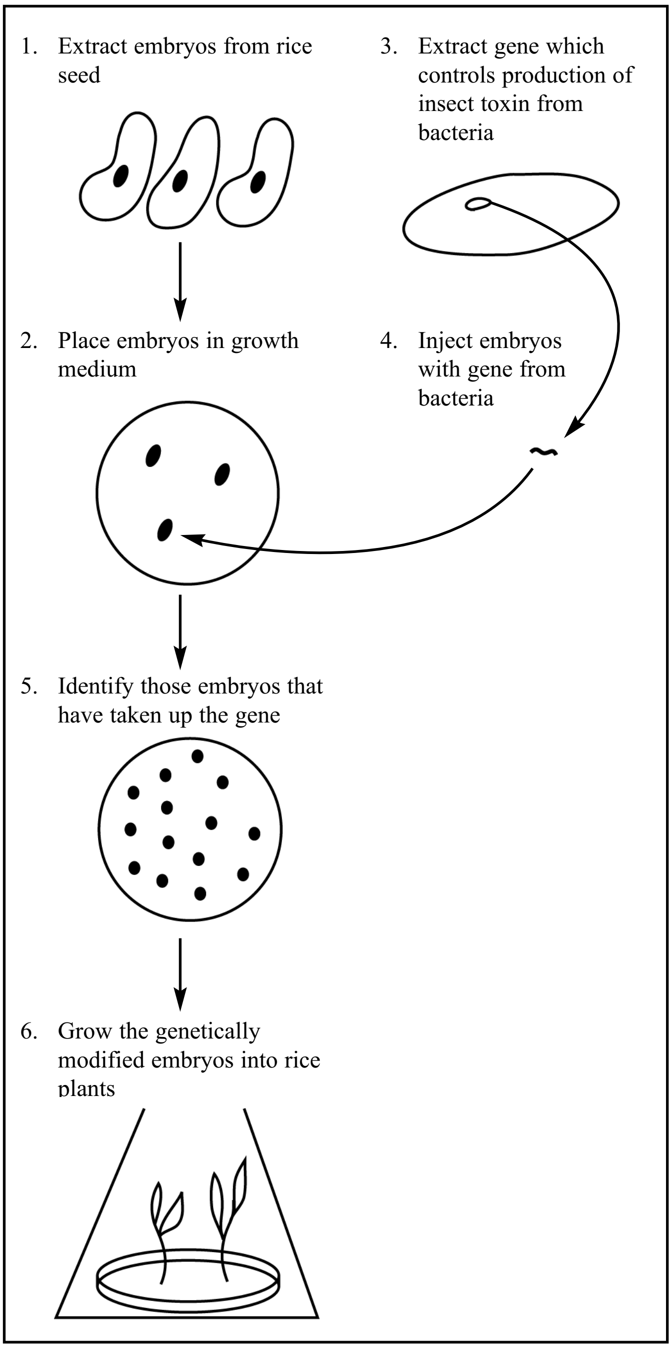


Exam Note: *In the exam, if the examiner tests you on this, the information in this diagram will be provided.*

Practice Exam Questions

1. Rice is attacked by many insect pests. Scientists have discovered a species of bacteria that naturally produces a toxin that kills many of these insect pests. The scientists have used genetic engineering to modify rice so that it too is able to naturally produce the insect toxin. *Fig. 6* shows steps in the production of this genetically modified rice.

Fig. 6 Producing genetically modified rice.



(a) Using the above example, explain the term **transgenic rice**. *(2)*

(b) Explain why it is hoped that this genetically modified rice will result in reduced pesticide application. *(2)*

(c) Outline one:
(i) ethical argument against the development or use of transgenic crops;
(ii) environmental argument against the use or development of transgenic crops. *(2)*

2. Suggest explanations for each of the following:

(a) Pollen from GM maize has been found at long distances from the GM maize fields; *(1)*

(b) Some environmentalists are opposed to the development of herbicide-resistant crops even though the manufacturers claim that this may reduce soil erosion. *(2)*

Markscheme

1. (a) Rice that has been given a gene from a different species; in this case, from a bacterium;

(b) Rice will produce toxin naturally;
If insect bites crop, it will be killed/ no need for pesticide;

(c) (i) Such gene transfer could not occur naturally so humans have no right to create unnatural gene combinations/ ref to animal rights/ some GE crops dependent upon finite resources/fossil fuels/ ref to multinational/developed countries controlling agriculture in developing world/ religious arguments based upon diet;

(ii) Ref to food safety/ novel proteins/ unpredictable effects on food chains/ may lead to greater use of fertilisers/ pesticides;

2. (a) Carried by wind/insects;

(b) May lead to increased use of herbicide;
so greater residues in food/aquifer contamination.

Sources of information

www.guardian.co.uk has a useful GM debate section
www.foe.co.uk has a lot of information as GM is one of its biggest campaigns. A very detailed report, suitable for A2 Biology, The Great Food Gamble can be downloaded free from their site.

Reiss, M.J, & Straughan, R. (1996). Improving Nature? The science and ethics of genetic engineering. CUP *An excellent, easy-to–read account of the whole debate.*

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