

Science and Society

(Robert May Science Year lecture, January 23rd 2002)

“In a quiz show, how else do you say right or wrong? You pick something with a clear answer, sometimes of course it’s just a trivial definition of things and sometimes it’s things that are substantial accomplishments. But the problem is, the reason why that is unfortunate, is that at and beyond the frontiers, that’s not what science is like.”

(Robert May, January 2002)

Plant Biotechnology and Genetically Modified Organisms (Activities 1-4)

Specifications

AQA Biology A Level

- Module 5(a): Environment (14.5)
- Module 6: Applied Ecology

Edexcel Biology and Human Biology A Level

- Unit 3: Energy and the Environment
- Unit 5B: Genetics, Evolution & Biodiversity
- Unit 5H: Genetics, Human Evolution & Biodiversity

OCR Biology A Level

- Module 2805,
 - component 03: Environmental Biology
 - component 04: Microbiology & Biotechnology

Advanced VCE in Science

- AQA Unit 5: Synthesising organic & biochemical compounds
- Edexcel Unit 24: Plant production systems
- OCR Unit 13: Using organisms for production

AQA AS Level Science for Public Understanding

- Module 1: Issues in the Life Sciences
- Module 3: Coursework – Study of a topical scientific issue.

Activities 5-7 are not subject specific and deal with issues about science in general.

“What further tests should we make of the genetically modified organism? What is their role in the future of agriculture? What future use is mainly looked to for them? May they help us realise the ‘dream of agriculture’? Growing crops not shared with weeds (plants in the wrong place) and not shared with pests

(insects with the wrong appetite)? How shall we proceed in this? There is a question that merges safety concerns with ethical concerns”
(Robert May, January 2002)

A Plant Biotechnology and Genetically Modified Organisms

Plant biotechnology involves the modification of plant performance for a particular purpose. For example,

- increasing yield
- enhancing tolerance to stress
- increasing disease resistance

Plant biotechnology also involves a large range of ways in which scientists can make use of the diversity present in the plant kingdom.

This includes,

- production of industrial raw materials such as oils, starches and biodegradable plastics (see later)
- medical applications such as the production of vaccines and therapeutic antibodies (see later)
- bioremediation techniques including ‘hyperaccumulation plants’ that can be used to mop up pollutants such as heavy metals from contaminated soils.

Producing genetically modified organisms (GMOs)

The production of modified nuclei by mechanical methods is fairly crude, so genetic engineers often prefer to exploit nature. Viruses existence depend on their ability to insert their own DNA into the genes of their hosts.

Reproducing GMOs

Any gardener who has tried to clear weeds knows well that some plants can regenerate from small fragments.

This works to the advantage of plant engineers, because single genetically modified or transformed cells, can be used to grow whole transgenic plants.

A different kind of genetic engineer, *Agrobacterium tumefaciens*, which induces growth in many plant species, has been widely used, although its use was initially limited to its natural hosts – broad-leaved crops like oil-seed rape and potato. Virus vectors that have been used in more recent plant experiments include tobacco mosaic virus X and cowpea virus but the expression of the new genes has so far only lasted for a short time.

Usually the desired gene is couple with one that produces a protein conferring a resistance to a particular herbicide, so that herbicide can kill off any untransformed cells.

Environmental issues

Groups concerned with the protection of the environment have raised many questions about the possible interaction of transgenic organisms with other species.

For example, an issue called 'genetic pollution' or that transgenic plants might export new genes to wild varieties of the same plant vial pollen dispersal.

This is not new – selectively bred plants can exchange genes with their relatives and wild ancestors.

Farmers try to prevent the oil-seed rape plants that produce food oils from cross breeding with the toxic strains cultivated for non-edible oils and test the crops to make sure such genetic pollution has not occurred.

Field trials of GM plants in the USA concluded that no such escapes have been detected between modified and unmodified plants.

It is worth noting that the distance between the crops is likely to be smaller in the UK and therefore would not offer the same degree of isolation.

Issues around GMOs

The first plant to be genetically modified was tobacco in 1983, followed by maize in the late 1980s.

It is only lately, however, that public concern and confusion has arisen. This since products such as GM soya have reached the European markets.

These concerns include safety, commercial interests, ecological and legal implications.

- Safety

While there is public concern over the safety of eating GM foods, there seems to be no scientific reason to suspect fully licensed GM crops, present any more of a safety problem than non-GM crops.

- Ownership
Some concerns focus on the fact that the ownership of many of the applications of GM technology seems to be concentrated in the hands of a few large corporations. As a result, it is possible that the same company that produces a herbicide-resistant crop, might also produce the herbicide with which it should be sprayed.....
- The environment
One concern is about the consequences of the cross-breeding of GM crops with wild varieties, e.g. producing weeds that are resistant to herbicides.
- Ethics
Each of the above concerns raises a range of ethical issues. For example, issues relating to the desirability and safety of GM products and processes in relation to the individual, the environment and on a world-wide basis.
- Legal
All genetic modifications must comply with very strict regulations. In the UK, genetic modification is controlled by European legal requirements, UK statutes, commissioned reports and reviews and several biotechnology and genetics advisory boards.

ACTIVITY 1

Either individually, or with a partner draw up a chart which addresses the issues around genetic modification.

The headings are given to you and some concerns are suggested – you may want to add some of your own.

(Note: your research for this will help with the debate later)

Concerns about GMOs

<u>Concerns</u>	<u>What do we know?</u>	<u>What do we want to know?</u>
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1. What will happen when we transfer genes from one organism to another?
2. Will the organism which is modified for one purpose (e.g. viral tolerance) change its behaviour so that it develops undesirable characteristics by becoming, e.g. invasive, persistent or toxic?
3. Will transferred genes escape from their host organism into others?
4. Does it matter if genes do escape?
5. Will the development of herbicide-resistant crops lead to reduction in wild-life biodiversity?
6. Is there a risk of introducing antibiotic resistance via GMOs?
7. What other effects might there be and can we target or control GMO products adequately?
8. Does an organism's DNA interact with the environment?

B Science and the Media

One of the basic problems with communicating the science of GM, and the issues surrounding the use of GM crops is that balance is boring....

The announcements from official bodies are usually made by men in grey suits at press conferences, while the pressure groups parade about in white space suits with alien masks!

The dramatic gesture makes much more interesting news.

It is worth noting that the newspapers and pressure groups have nothing to lose and everything to gain from negative stories.

The newspapers want maintain or increase their circulation and the pressure groups want to win converts.

Another difficulty is “soundbite science” or how to communicate sometimes rather complex science in a few snappy sentences. It is easy to destructive in a soundbite, but somewhat more difficult to create balance and build confidence.

ACTIVITY 2

Produce a 60 second soundbite for a news item on GM.

You need to explain recent advances together with the advantages of GMOs. Use the world food problem as the context.

If possible record everyone’s attempts and compare content.

A worrying aspect of the current media debate is that science and scientists are often misrepresented.

The public remember the rare failures and forget the very many successes – “science is the root of our problems”.

Life expectancy is greater now than 50 years ago and science has made an important contribution to this.

ACTIVITY 3

Write an article (300 words) showing how GMOs can improve life expectancy, particularly in developing countries.

It needs to be ‘reader-friendly’ and positive about GMOs – you are trying to allay fears.

The Future

- GM crops will become an important part of world agriculture in the next 20 years.
Just as the food requirements of today’s population of 6 billion could not have been met by the technologies of the 1940s, so we cannot assume that current practices will feed the population of 8 billion expected by 2020.

- In 1999 there were almost 40 million hectares of GM crops grown world-wide – the largest area was in the USA, followed by Argentina, Canada and China.
- The advent of GM over the last 20 years has enabled plant breeders to develop new varieties of crops at a faster rate than was possible using traditional methods.
- GM plants have been produced to improve insect tolerance and virus resistance and to include herbicide tolerance, so that other plants such as weeds may be eradicated without harming the crop species.

In China about half of the rice crop is from hybrid varieties, the first of which was introduced over 25 years ago, during the Cultural Revolution. Because hybrid varieties are producing substantially higher yields than the non-hybrid varieties, farmers are willing to buy seeds every year rather than use seeds they have saved from the previous year.

About 5 years ago, China lost 30-50% of its cotton crop to pest attack, so pest resistance is important to them.

What else can GMOs do?

1. Plants make plastic

An intriguing possibility currently being explored is the production of the raw materials for biodegradable plastic by genetically modifying oil-seed rape. The production of these crops would substantially reduce costs and widen the use of biodegradable plastics in areas such as packaging.

2. Designer oils

Advances in plant genetics have revealed the biochemical pathways by which plants make oil. So it is now possible to use genetic modification to alter the composition and properties of these oils far more quickly and precisely than with traditional breeding techniques.

3. Bio-pharming

Transgenic plants that express foreign proteins with industrial or pharmaceutical value promise an economical alternative to the fermentation-based production systems which use genetically modified microbes. Researchers have produced vaccines in plants as the result of the expression of foreign genes. This indicates the possibilities for the 'bio-pharming' of vaccines. If the antigens are food-based, 'edible vaccines' could be very effective against many infectious agents, such as those transmitted in contaminated food and water – a particular problem in developing countries.

The use of GMOs has the potential to offer real benefits in agricultural practice, food quality, nutrition and health. There are, however, uncertainties about several aspects of GMOs and continued research is essential if these uncertainties are to be properly addressed, the risks understood and the full potential of the new technology made clear.

ACTIVITY 4

A Public Enquiry

This is a debating activity.

It will require two speakers for and two against the motion, with a chairperson controlling the proceedings.

Each speaker has 5 minutes to speak and this should proceed uninterrupted. The audience will then have the opportunity to ask the speakers questions and the debate should conclude with a vote.

The motion for debate is:

“GMOs are perfectly safe and their widespread use will solve the problems associated with disease and food shortage in the countries of the developing world”

C Certainty and uncertainty

Scientists sometimes come in for criticism. Society believes that they should have answers to important questions, such as 'are genetically modified crops harmful to the environment?', or 'are mobile phones safe?'. But they don't have simple answers – yes, or no for instance. Many people do not understand this – surely science is based on objective knowledge – reliable and there to come to the aid of society when problems arise. After all, the science we learn in school is fact – we need to know the facts about MMR. Or global warming – is it happening, what will it mean for the UK climate?

There are some areas of science which can provide us with answers to questions. Most of science is like that – science that has become accepted as being reliable. To quote Professor Lord May,

There have been advances that have hardened into virtual certitude. But the problem is that at and beyond the frontiers, that's not what science is like. And many of the problems that we wrestle with, and will increasingly wrestle with in future years, are problems at and beyond the frontiers of science where we don't yet know, we will sometimes have good guesses. We will sometimes have a better way of raming the question. But very often we won't have an answer.

(Taken from Professor Lord Mays Science year Lecture at the Royal Society, 23/1/02).

ACTIVITY 5

- Write a list of five ideas from science which you would say are 'hardened into virtual certitude'. An example might be '*that enzymes help to speed up biological reactions*'.
- For each of your examples describe a piece of evidence which supports the idea.
- Write down of one idea from science which you think is still controversial, where there may be some disagreement about whether or not the idea is reliable. An example might be '*that living near high voltage power lines causes cancer*'.
- For your example, list the evidence which supports the idea, and evidence which might tend to refute it. This might include criticising the *evidence in support*, rather than listing evidence which refutes the idea.
- What do you think is the main reason why the idea you have suggested is controversial.

ACTIVITY 6

You will be given a card which contains a scientific idea. Think about the idea in terms of how certain we are that the idea is reliable. Place your card somewhere on the *Uncertainty Continuum*.

You will each in turn have to explain why you put the idea on a particular point on the line, between *certain* and *uncertain*.

To explain certainty, you need to identify the supporting evidence. To explain uncertainty, you will need to identify why the evidence is not sufficient for us to be certain of the idea.

The ideas are

Human life evolved, it was not created	Plate tectonics explains the distribution of mountain ranges, volcanoes and earthquake zones
Blood circulates round the body in blood vessels and is pumped by the heart	The planet Earth is part of the Solar System, which is part of a galaxy
The greenhouse effect is real and is causing global warming	HIV causes AIDS
MMR vaccination is safe	Acupuncture can cause physiological changes in the body
Metal canisters can be used to store sources of alpha radiation safely	The microwave radiation from a mobile phone is not harmful
The dinosaurs were wiped out following an asteroid collision with the Earth.	The Universe started with the Big Bang
There is life elsewhere in the Universe	Matter is made up of atoms
Genetically modified crops will not harm the environment	The boiling point (in °C) of water is dependent on the air pressure.

Ideas cards

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D Writing a media story

Many people learn more about science from the media than they do from anywhere else. Look in most daily newspapers and you will probably find at least one story about science. The problem is, to get an article past the editor into the newspaper the journalist may have to sensationalise things a little.

The following is a list of the types of 'angle' which journalists – whether it is newspapers or TV news – use to make sure the story gets published.

The people factor – is there a human angle to it? Will people feel emotionally connected with the story? Will it make them happy, sad or angry? The trouble is that human interest stories often focus on one or two anecdotal incidents or examples – the parent whose child reacted very badly to the MMR vaccination is used to make it look like MMR is always harmful. Medical evidence indicates that it is not, but the story suggests otherwise.

Weird science – Quirky stories are popular. Scientists are often portrayed as being different to everyone else – the boffin or mad professor. Put these two together (although they work on their own) and you have a sure-fire hit – “Frankenstein scientists clone a sheep”. The media are not always the best people to address the ‘negative stereotype’ of the white coated, clip-board carrying researcher.

It affects me! – Something new that has the potential to affect people’s lives – Tommorrow’s world does this a lot. “Vacuuming the carpet will become a thing of the past because of a new invention. CUT TO a scientist with a new gizmo which automatically extracts the dust from the air. In most cases we never see the invention again. Sometimes they get it right - the catalytic converter, the microwave, the DVD. All these have changed people’s lives.

Discovery – New facts and theories are always good news, particularly if they are about things such as life on other planets, space travel, the origin or age of the Universe, human evolution and the human genome. The trouble is journalists often mistake a speculative theory with hard facts. What a scientist may suggest as an explanation could seem to be a true fact when written about in the wrong way.

Visuals – A good picture or piece of video makes any story more interesting. A talking head is better than just the newsreader, but a shot of real people doing real things is even better. Best of all – animals.

ACTIVITY 7

You are going to be a reporter. You can choose which type of media you work for – it could be a newspaper, a radio station or a TV news programme. You will be given a job card, which outlines a news item you will have to write about or make a broadcast item for.

The news items are all based on science you have probably studied. Some are really old – some are more recent. Your job is to produce:

- a 200 word newspaper story OR
- a 90 second radio news item OR
- a two minute TV news item

For the radio and TV items, you can either perform them live in class, or record them on tape or video.

Use the list showing the five features of a good media story to help you get an angle. Try to address at least one, and possible two items from the list. Try to imagine what it might have been like when the new discovery or invention first became known. Who might have been affected by it? Was it something which would change peoples lives? If so, imagine you were interviewing someone who would use the discovery or invention, or someone who would directly benefit.

It could be a good incentive to produce a top story if there is a prize for the best one!

Job Cards

The Human Genome Project	The discovery of vitamins
Darwin and natural selection	Plate tectonics
Newton's laws of motion	The periodic table
Discovery of fullerenes	Invention of the microscope
Black holes	Discovery of the electron

Useful References

- Dale, P.J. (1999) Public reactions and scientific responses to transgenic crops. *Current Opinions in Biotechnology*, **10**, 203-208
- Leake, A. (2001) Integration: farm and environment. *The Biologist*, **48** (4), 159-162
- Bioethics Report on GM food, The Nuffield Council (1999), 28 Bedford Square, London, WC1B 3EG
- Ethics, Morality and Crop Biotechnology, Straughn, R. & Reiss, M (1996)
- BBSRC, Polaris House, North Star Avenue, Swindon, SN2 1UH
- Food for our future, Food and Drink Federation (1996), 6 Catherine Street, London, WC2B, 5JJ. <http://www.foodfuture.org.uk>
- GM Agriculture in the UK, BBSRC (1999)

Websites

- GM Plants for Food Use: <http://www.royalsoc.ac.uk>
- Genetics Forum: <http://www.geneticsforum.org.uk>
- Importance of plant hormones in biotechnology: <http://www.plant-hormones.bbsrc.ac.uk/education/keni/htm>
- Institute of food and technology: <http://www.easynet.co.uk/ifst>
- National Centre for Biotechnology Education: <http://www.rdg.ac.uk/NCBE>
- Pharmacia: <http://www.pharmacia.com>
- Science and plants in schools: <http://www.saps.plantsci.cam.ac.uk/info/refsum/html>
- UN Food and Agriculture Organisation: <http://www.fao.org/WAICENT/>
- The Royal Society: <http://www.royalsoc.ac.uk>