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Agricultural Biotechnology in an Ethical Context

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Executive Summary

The introduction of some agricultural biotechnologies in New Zealand has created considerable controversy. The main objections concern possible harm to man, damage to the environment and discomfit about the 'unnatural' status of the technology. The report has therefore examined the ethical issues that are raised by the development and application of food based biotechnologies. Three ethical principles have been used in that examination:

1) the principle of general human welfare
2) the maintenance of people's rights
3) the principle of justice.

A framework using the three ethical principles has been advanced with the aim of reducing the controversy and leading to optimum outcomes.

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5. Introduction

The introduction of genetically engineered food and the potential growth of genetically engineered crops in New Zealand has recently created considerable media attention and public debate. New technology creates change and logically will only be accepted if it provides a net long term benefit to the users of that technology. Some cultures have failed to adopt potentially beneficial technologies, and others have adopted and then discarded technologies. Aborigines of North-eastern Australia failed to use bows & arrows which they saw being used by Torres Straits Islanders with whom they traded, and Japan adopted and then discarded the use of guns. (1)

Four main factors affect the uptake of new technology within a society:

1. Relative economic advantage compared with existing technology.
2. Social value and prestige.
3. Compatibility with vested interests.
4. Ease with which advantages can be observed. (2)

Ethics is not specifically included in this list. It has been proposed that the use of modern biotechnology should be based on ethical decisions, (3) or that a comprehensive code of ethics would aid acceptance and decision making in this area.(4)

New Zealand as a country currently uses some highly sophisticated plant and animal breeding techniques. We have a choice as to how far we go with the introduction of modern biotechnologies. It is important that we make the correct choices.

'Like most tools, like most scientific knowledge, biotechnology in itself is neither good nor bad. It can be used well, or it can be used badly. Like any important new tool, it creates new choices for society. Most of the tools that people have used throughout our history ...have had the same kinds of characteristics...They're all tools. They all create possibilities for people. Some of those possibilities are attractive and empowering, and some of those possibilities are less attractive and potentially damaging.' (5)

New Zealand has regulatory bodies that assess the safety of novel foods(ANZFA) and the risks posed to the environment of new organisms (ERMA). There are issues that need to be addressed, such as the trade implications of introducing some biotechnologies, that lie outside the scope of the safety to man and to the environment.

This report will describe ethics, and biotechnology, and will discuss the ethical issues associated with biotechnologies and will provide a framework for assessing them.

6. Biotechnology

Biotechnology can be described as a set of scientific tools which uses living things to solve problems and to make products. (6.) It can also be defined as "applied biology" or "the use of living organisms to make a product or run a process." (7) It includes such old practices as the use of yeasts and bacteria to make bread, beer, wine & cheese. "Traditional" biotechnology is also used to extract and purify parts of plants and animals to make drugs, cosmetics and foods. Some people use the term biotechnology to refer to the newer tools of Genetic Engineering developed since 1973 e.g. NABC, ad hoc Subcommittee on Ethics (8) . It does however refer to a whole range of techniques including:

1. Amplification - The increase, spontaneous or induced, of the number of the same gene within a cell.

2. Bioremediation - The breaking down of industrial waste by micro-organisms

3. Cloning - Making a group of genetically identical cells or organisms asexually descended from a common ancestor. (some cloning techniques are centuries old)

4. Genetic engineering - The process of modifying the genetic material of a cell using restriction enzymes.

5. Replication - The formation of new strands of DNA from existing DNA.: (7 p1430)

A history of biotechnology is provided in appendix 2.

Agricultural biotechnology is simply biotechnology that can be used in agriculture. Genetic engineering is defined in the next section and then compared with conventional agriculture. The reason for this is because it is the area of biotechnology that has generated the most controversy.

6.1 Genetic Engineering, a Definition

The Hazardous Substances and New Organisms Act (1996) states that:

> 'Genetically modified organism' means .....any organism in which any of the genes or other genetic material -
> (a) have been modified by *in vitro* techniques; or
> (b) are inherited, or otherwise derived from, through any number of replications, from any genes or other genetic material which has been modified by *in vitro* techniques.(9)

The definition covers both inter- and intra- specific transfer and all offspring of these for an unlimited number of generations.

In the wider community there is some confusion on a definition. The Grocery Industry Council in a public information booklet defines GM as "Genetic Modification is the process by which genetic traits can be copied and transferred **between** species." (emphasis added)(10)
The intra-specific transfer is excluded from this definition.

The Independent Biotechnology Advisory Council describe GM as; "genetic engineering allows a gene, or genes in any living thing to be removed, turned off or shuffled around. It also allows genes to be moved from one species to another....."(7,p10)
This is much closer to the legal definition.
(n.b. Genetic Engineering and Genetic Modification are synonymous)

The Nuffield Council on Bioethics (NCB) uses an inter-specific definition: "The genetic modification of plants involves transferring DNA, (deoxyribonucleic acid), the genetic material, from a plant or bacterium, or even an animal, into a different plant species."(11)

The different definitions are informative and add to some of the public confusion on GM. Intra-specific modification on the face of it presents less of a philosophical problem than inter-specific modification. It is therefore important that it is clear what is meant by GM.

The HSNO Act's definition is the most appropriate for this report.

6.2 Genetic Engineering compared with Conventional Breeding

The ancestors of the current suite of domestic plant and animal species are on the whole vastly genetically different from their wild relatives. All domestic species have been modified continuously since their domestication.
Conventional breeding in its simplest form is the crossing of two individuals of the same species, where the offspring gets half of its genetic material from each parent. There is no way of controlling the genes that are transferred. Historically to obtain the best of the parents a large number of crosses are carried out then the best of the progeny are selected over a large number of generations. With the knowledge of gene markers and DNA it is now possible to speed that process up by taking tissue samples of all progeny and selecting on markers rather than phenotypic expression. (12)

Genetic modification on the other hand allows a specific gene to be transferred or modified. Once the modification of the gene has been done, offspring that will contain copies of the new gene can be produced in the conventional manner. GMs advantages are that it is very targeted and efficient, and that there are some combinations of DNA that are possible which would not have occurred through conventional breeding.

Modern conventional breeding is also very sophisticated. It is possible to move genes across sexual barriers through embryo/ovary culture. Hybridisation is possible. Mutation breeding is common as is induced mutation through irradiation treatment. It is also possible to change the number of chromosomes in a plant e.g. tetraploid ryegrass.

6.3 Regulatory Framework

Food Safety
Under current food safety laws manufacturers are required to ensure that all food is safe. GM food has been deemed to be different and will be assessed on a case by case basis by the Australia New Zealand Food Authority (ANZFA). ANZFA will use the principle of substantial equivalence to determine food safety. Key comparisons of composition, nutritional value, toxicity, and allergenicity are made between GM food and its conventional counterpart. If these aspects fall within the same range then the GM food is deemed to be as safe as the same aspect of the conventional food. If the GM food is different then ANZFA will require additional information to determine that the food is safe. (13).

Environment
The Environmental Risk Management Authority's first obligation is to fulfil the purpose of the HSNO Act - to protect the environment and the health and safety of people and communities. It must also take into account:

*the sustainability of all native and valued introduced flora and fauna.

*the intrinsic value of ecosystems.

*public health.

* the relationship of Maori culture and traditions with their ancestral land, water sites, waahi tapu, valued flora, and other taonga.

* the economic and related benefits to be derived from the organism.

* New Zealand's international obligations.

The HSNO Act also requires caution in decision making as some organisms once introduced will be difficult to recall.(14)

7. Ethics

Ethics is as problematic as biotechnology or GM to define. Ethics is concerned with what people ought or ought not do. Ethical principles provide the standards for the evaluation of policies or practices (15) Ethics is also about the values that we place on different relationships (the Human and the Non-human world) and about deciding which relationships are appropriate and which ones are not. (16).

In a laboratory research or company director situation ethics may narrowly be understood in terms of personal integrity. The US public tends, where biotechnology is concerned, however to interpret ethics more in the manner of philosophers. Philosophers apply logic and a tradition of articulating and defending answers to the questions "what should we do?"
"The main contribution of philosophical ethics to the study of food and biotechnology is an increase in the clarity and precision of normative claims (claims that something is good, or right, bad or wrong), and a greater sensitivity to the range of normative claims that might be made by others with a different vantage point or a different conceptual strategy for think ing about ethical issues."(8)

Fisher describes agricultural ethics as .."a means of identifying and clarifying in a logical and rational manner, the complex of factors that determine concepts such as animal welfare. It is a science-based ethical evaluation of the impacts, consequences, different viewpoints and claims of agriculture, undertaken on behalf of the agricultural sector, to ensure that producers, consumers, society, future generations and the environment are not exposed to unacceptable risk of harm and are cognisant of the ethical considerations of farming." (17)

The Royal Society of New Zealand Code of Professional Standards and Ethics has ten headings:

* *Integrity and professionalism*
* *Honesty*
* *Competence and standards*
* *Relationship with colleagues*
* *Relationship with the community*
* *Relationship with funders of research*
* *Relationship with paying clients*
* *Environmental considerations*
* *Use of animals in research and teaching*
* *Educational responsibilities*

Ethics is therefore much broader than just personal integrity and includes an educational component.(18)

7.1 Ethical Principles

The Nuffield Council on Bioethics uses three main types of principle to evaluate GM crops.

1) *General welfare* which enjoins governments and institutions to promote and protect the welfare of citizens.

2) Maintenance of peoples *rights* e.g. the right of consumers to choose to consume GM foods or not.

3) The principle of *justice* which requires the burdens and benefits of policies or practices to be fairly shared among those affected by them.(19)

Fisher uses four principles derived from medical ethics to provide a framework for an ethical evaluation:

1) Autonomy or freedom to make our own decisions:

2) Justice or fairness

3) Non-maleficence or an obligation not to harm: and

4) Beneficence or an obligation to do good. (17, p.2)

These four are similar to the principles of general welfare, justice and rights, and can be seen as such if beneficence and non-maleficence are combined as the principle of general welfare.

An ethical examination may have three stages (1) the relevant scientific facts and appropriate ethical criteria are established; (2) an ethical analysis is formed by combining these two, (3) the result is interpreted with respect to your own attitudes or ideological viewpoints. (20 p.11) The examination can be supplemented with narrative to include the different perspectives of people with differing backgrounds.

In respect of point (3) above it is important to outline the researcher's values and beliefs. The Nuffield report is "grounded in liberal, scientific values and takes a broadly utilitarian approach to ethics, a starting point which is shared by most people in the UK." (11 p.4). Here utilitarian means that what ought to be done is guided by the goal of achieving the greatest happiness for the greatest number of people. This report takes a similar approach but limits the utility to New Zealanders. Limiting the utility primarily to New Zealand is because New Zealanders as a whole are unlikely to be so altruistic as to take on significant risk for the benefit of others. e.g. The researching and breeding of GM crops that could help alleviate hunger in developing countries could provide significant risks to our trade with Europe without offering commensurate benefits.

8. Ethical Issues with Biotechnology

The ethical issues associated with agricultural biotechnology are usually special cases of general questions raised by the introduction of any technology. A case-by- case basis is recommended for the evaluation of biotechnologies as there is such a diverse range of possibilities.(Bezar H cited in 21).
The main issues are discussed briefly below.

8.1 Environment

Will the technology damage or benefit the environment? Roundup ready crops, as an example, are purported to create a reliance on herbicide applications but when compared to conventional growing of those crops, actually lead to an overall reduction in herbicide use, and the use of a safer herbicide. Weed control can be carried out with a non-specific herbicide (Roundup) after crop emergence. This compares to the possible use of a pre-emergent herbicide and then a specific herbicide post emergence.

Bt cotton has reduced the number of chemical applications on some crops from ten to two. (12)

There are risks, cross-pollination with wild relatives could create problem weeds, pest resistant crops may lower biodiversity or lead to insecticide resistant pests. A proactive approach is suggested for the environmental risks, "To deal with concerns like these we must be seen to be placing prevention now ahead of a possible cure later." (22 p.7))

Biotechnology may allow greater production from a finite land resource which would allow more land to be left in its "natural" state. It could also allow the production of animals or crops outside of their present ranges thus reducing the size of the worlds conservation area and decreasing biodiversity. The general welfare of providing food to the world must be balanced with the overall welfare of the planet and its inhabitants.

The argument of feeding the worlds growing population is often used to support newer biotechnologies. It is a powerful argument, but if the world is able to produce more food will the population not just expand to consume that extra production capability? And so it goes on. Any group of organisms must live within the constraints of their environment i.e. in a dynamic balance. At some stage man must reach this balance. If biotechnology prolongs the point of reaching this balance, does it promote the general welfare? What affect does it have on current and future citizens rights? Is it Just? And what effect does it have on our relationships with the non-human world?

8.2 Public Health/Food Safety

Three key concerns are raised with regard to public health and food safety - allergens, toxins and antibiotic resistance. The first two present issues that are the same as for any new food products.
Antibiotic resistance genes have been used as marker genes in the GM process. Hyde has calculated the likelihood of resistance transferring to humans at about one in a trillion.(21 p.34)
Even so, Conway recommends that their use be discontinued, (22 p.10).
The general public must have confidence in the the regulatory bodies (ERMA & ANZFA) that oversee the introduction of new products and technologies.

8.3 Social & Consumer

One way to promote general welfare is to ensure that consumers have a choice since they will generally choose what is best for them. Even if they do not do what is in their own interests e.g. cigarette smoking, they are exercising their rights and freedom in so doing. It is not unethical to smoke tobacco, merely unwise. It would be unethical to market tobacco if consumers were not informed of the risks involved.

There have been many calls for the labelling of GM foods to be compulsory. The market can and is providing products that are GM free e.g. organics. A demand for consumer choice not based on the avoidance of harm needs to be justified in the context of regulation. "Claiming a right to have a product made available when the market would not otherwise have supplied it presents grave difficulties. It is one thing to insist that suppliers guarantee not to poison the customer; it is another to insist that companies should supply any particular range of products." (19 ch1).

Another side to the labelling issue is religious or other groups who object to consuming organisms containing specific genes. Some vegetarians object to consuming plants into which copies of animal genes have been added, and Muslims, Sikhs and Hindus object to consuming organisms containing copies of genes from animals that are subject to religious dietary restrictions. Maori regard genetic engineering as culturally and spiritually unacceptable. (6 p.14) GM organisms are even claimed to threaten the life of Maori. (24 p13).

The FDA prohibits the use of misleading labels even if true. e.g. 'this milk was derived from cows not injected with bST' unless accompanied by a statement clarifying that there is no difference between milk from bST-treated cows and untreated cows. (7 p.1431) The label 'GE Free,' in that context, may be misleading and unethical?

8.4 Commercial/Intellectual Property & Patenting

Companies that develop biotechnologies will generally only do so if they gain a return on their investment greater than their cost of capital. The costs of genetically modifying a crop and testing and introducing to the market place are huge. So high in fact that to gain a return on investment, research is usually focused on the more widely used crops. Also to have the scale and size necessary to carry out the research and gain a return, entities have to be large. Those entities also wish to protect their investment by patenting the technology. These facts present some ethical problems. For example:

1) Is it just only to apply research to the main crops? What about farmers in poorer areas who use minor crops?

2) Will the benefits be equitably distributed, or captured by larger 'profit seeking' multinationals?

3) Where is the balance between the rights of companies to protect their innovations and the rights of farmers to save and re-use seed?

8.5 Developing World

Biotechnology promises to help the developing countries more than the developed ones. 'The abolition of hunger may be our most important ethical drive'.(Suman Sahai in 23). Developing countries on the whole are not having the level of controversy over GM that developed ones are. They are also likely to have differing priorities and values than our own.

The world's problems of under nutrition are often claimed as distributional problems, with over nutrition in some areas and under nutrition in others. This is often argued as negating the need for increased food production. Current biotechnologies, such as the use or manipulation of genes that control ripening, could greatly improve human survival and health in countries such as India where up to 60% of fruit grown in hill regions rots before it reaches the market. (23)

The Nuffield Coucil on Bioethics argue that the fact that most hunger is due to a lack of employment income ***strengthens*** the case for raising food productivity on small farms in developing countries, to increase the employment opportunities.(11 ch4.19).

It would promote the general welfare of the world if the benefits of biotechnology were applied where they were most needed. Ethically this would be just. It seems an unlikely proposition however, given the developed worlds current predilection with subsidising farming and protecting their markets, which has a large negative affect on producers in developing countries, and could be viewed as unethical.

If biotechnologies get more investment and research in developed countries than undeveloped ones, the gap between rich and poor may be widened. What about the rights of the citizens in the third world?

8.6 Natural/Unnatural Boundary

The natural/unnatural debate is hard to place in the context of welfare, justice and rights. It is however important in an ethical analysis to look at the philosophy and values inherent in the debate.

Moving genes from one species to another can be viewed as unnatural. Many people object to GM on this basis. (11 ch1.37) Biotechnology use in medical circumstances has not attracted the same scrutiny as food and agricultural uses. Society appears to draw a distinction between ‘unnatural’ techniques in agriculture and medicine.

The concept of nature varies with all people. From one perspective, man and his impact on the world is natural. Conversely that impact could be viewed as totally unnatural. Smallpox is natural but deemed worthy of eradication. Waves of extinctions have naturally occurred following mans’ colonising of any land.(1) This does not mean that extinctions are right.

As a farmer and breeder of livestock it is important to work within the forces of nature. Extending the performance of any single trait such as fleece weight, growth rate or milk production as far as possible tends to compromise an animals ‘fitness’. The first aspects of fitness to be affected are usually reproductive efficiency and disease resistance. Many current domestic species would not survive without the management of man. Is that natural?

The world is much changed from when man first domesticated plants and animals.

“Is a plant natural if it has been successively bred to have a particular gene complement, but unnatural if precisely the same gene complement has been arrived at through laboratory processes? We can see no reason in ethics to draw a distinction.” (11 ch1.40)

“I don’t feel that it is unethical to transfer genes across species boundaries because we are finding that most of the genes involved in basic cellular processes are virtually identical across all species.” (Connor T cited in 25, p19)

9. A Framework for An Ethical Appraisal of a Biotechnology --- *White clover modified to resist frosting*

(Adapted from Fisher M (17)& (20))

Some antarctic fish have a gene that produces an antifreeze agent to allow them to live in the salt water at temperatures below zero centigrade. Some assumptions are made to perform this analysis.

1) it would be possible to transfer this gene into the white clover plant.
2) the only effect of the gene is to lower the soil temperature that white clover can grow in.
3) the nutritional composition of the white clover would be unaltered.
4) no traces of the modification would be found in the food chain.

Affected Party	Justice	Rights	General Welfare
Livestock	Advantage to grazers	No choice	Better year round nutrition
Maori	Anti Maori	Impact on Treaty	
NZFarmers	Less need than others	Free to adopt	Lower costs Greater production High reliance on few cultivars
Third World Farmers	Expensive technology	unable to use	Competitive disadvantage
European Farmers	Allows to compete with temperate zone.	Free to adopt	Allows the use of clover based pastures.
Consumers	Little benefit?	unlabelled products no choice	May lower costs
Organic farmers	Negative affect	Impacts on freedom to carry out business	Lower profits through consumer resistance
Beekeepers	Negative	No choice	Consumer resistance?
Society	Little benefit Cheaper food	Hard to label no right to choose	More even price for food Flow on effects of profitable farmers
Fertiliser co's	Same affect to all		Lower N sales Higher S sales
Environment	Increase clovers ability to compete		Less N fertiliser Clover now viable in subalpine
Wildlife	Change pasture dynamics		More pasture systems

The key beneficiaries of the technology would be farmers and the breeders of the seed. Farmers benefits are increasing the growing season for clover in the winter months, which enhances pasture composition at those times and allows for greater nitrogen fixation. The other major benefit is the reduced reliance on nitrogen fertilisers for cool season pasture growth, reducing the associated environmental problems. Few other entities gain significant benefits. Organic farmers, Maori and beekeepers are the major losers. The perception of having transgenic clover in New Zealand may affect organics consumers. The technology also adds to the cost of production disadvantage organic producers currently face. If the technology was accepted by organics consumers, organic farmers would benefit more than conventional ones.
Conservation land would be affected by the increased ability of white clover to compete in high fertility colder zones. Spread of the seed would be inevitable and irreversible and the ecological balance would change.

Ethically the welfare balance lies between the benefits of a more 'organic' form of N in the cooler months and the cost to the affected entities who have no right to choose whether to adopt or not. The benefits are not shared equitably and only the users of the technology have any rights of choice. If the precautionary principle is followed where does the balance lie between the avoidance of harm and the achievement of a positive good?

10. Discussion

Is this type of approach useful? Does the ethical appraisal help us, or policy makers, to decide what ought to be done? Would it benefit introducers of biotechnologies to assess the implications of their technology on other parties? Can it be used by those opposing a particular technology to better understand it?

Monsanto the company most associated with biotechnology in New Zealand started 20 years ago with "a conviction that biotechnology is a good technology, and is safe, useful and valuable" (5). They have then tried to convince (as opposed to educate) people that that is indeed the case. This approach has not worked and now their language is of dialogue and openness. If they used the ethical framework outlined above and linked it throughout their business from research to customer, would they be in the same position today? Some consumer unease and society resistance could have been foreseen. They may have had a 'greater sensitivity to the range of normative claims' that have been made by others.

It must be noted here that the framework could be used by biotechnology companies in two ways.

1) Identifying potential barriers to introduction so that ways can be found around them.

2) Identifying and understanding the complete range of viewpoints and accommodating and working with the reasonable majority to obtain the best outcome.

Ethically the second option is the best. It maximises welfare, ensures the greatest equity and helps to maintain rights.

IBAC is currently grappling with the consequences to New Zealand of the introduction of GM plants. The key questions for them are the issues surrounding the impact on organic farmers. (26) They are now developing a framework to look at the economic, trade or other advantages (or otherwise) of restricting the release of GM crops.(27) An ethicist is included on their board and it is likely ethics will be included in that framework.

Greenpeace the global anti-nuclear/conservation organisation has come out strongly against GM plants for food use. It appears the GM issue will help to strengthen and rejuvenate their global brand. Biotechnologies and GM plants as discussed could do much for conservation and making the world a better place. An ethical appraisal of technologies on a case-by-case basis, while lacking the current popular appeal of a simple anti-GM message, could help to create the best outcomes for Greenpeace's overall conservation goals.

A problem with the framework is that much of science and technology involves small incremental advances in knowledge. Deciding when to conduct an ethical appraisal for those smaller advances presents problems, firstly in identifying the advances and secondly in deciding if they warrant a full appraisal.

Sometimes the uses and implications of technology are hard to foresee. James Watt designed his steam engine to pump water from mines, it soon was supplying power to cotton mills,then propelling locomotives and boats.(1 p244)

These problems aside, there are many cases where the framework described would help.

Ziman argues that academic and industrial scientists have both been insulated from ethics for two distinct reasons. Changes in science are forcing scientists to become more sensitive to ethical issues. (29) The above framework will help in this increased sensitivity.

An ethical appraisal does not provide an answer, it only helps clarify things. If ethics can however be linked with the science, and with all aspects of the introduction of biotechnologies, it will lead to greater understanding by all parties, and to optimum outcomes.

11. Conclusion

Agricultural biotechnology is a complex area of technology. It raises issues of safety to man and to the environment. Other issues are also raised. The use of ethics provides a means of assessing all these issues. The consideration of three ethical principles, general welfare, justice, and rights, in a formalised framework will help to provide clarity to the issues surrounding the introduction of agricultural biotechnologies. It will identify the parties most likely to be affected by a biotechnology and enables a sound understanding of their concerns. It also works the other way and allows all parties to have knowledge and be aware of the position of the introducers and users of that biotechnology.

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13. Appendices

13.1 Appendix 1

Historical Development of Plant Breeding

1694 Discovery of sexual reproduction in plants

1719 First recorded plant hybrid (intraspecific hybridisation)

1799 First report of cereal hybrid

1866 Mendel publishes his work with pea crosses

1876 Interspecific and intergeneric crossing (leading to Triticale Wheat x Rye cross) (Triticale now grown on 2 million hectares)

1900 Start of hybrid maize breeding in USA

1909 Protoplast fusion reported

1927 Mutation via x rays

1937 Polyploidisation

1940s Single seed descent technique developed (SSD)

1960s Embryo rescue refined

1970 Recombinant DNA technology (start of modern biotechnology)

1970s Double haploid techniques

1983 First genetically modified transformed plants (tobacco)

1990 First genetically modified cereals

(Source: 28)

13.2 Appendix 2

History of Biotechnology

The word 'biotechnology' can be traced to 1917 when it was used to refer to large-scale fermentation production techniques.

4000 BC	Egyptians use yeasts to make bread and wine.
1750 BC	Sumerians brew beer.
250 BC	Greeks use crop rotations.
1500 AD	Aztecs make cakes from Spirulina algae.
1663	Cells are first described by Hooke.
1859	Darwin publishes "On the Origin of Species"
1866	Mendel proposes basic laws on genetics based on studies with pea plants.
1910	Genes are discovered to be located on chromosomes.
1941	The term "genetic engineering" is first used.
1944	DNA is shown to be the hereditary material in living organisms.
1953	The double helix structure of DNA is discovered by Watson, Crick & Wilkins.
1969	The first gene is isolated.
1973	The first GE experiment is conducted by inserting a gene from the African clawed toad into bacterial DNA.
1978	The first test tube baby born.
1981	The first gene synthesising machines are developed.
1982	The US FDA approves the first GE drug, a human insulin produced by bacteria.
1983	The first transgenic plant is created - petunia plants genetically engineered to be resistant to kanamycin, an antibiotic.
1985	NZ develops a hormone extract product from sheep, used to induce reproduction.
1985	DNA fingerprinting first used in a criminal investigation.

1986	The first field tests of GE plants (a tobacco) are conducted.
1990	Chymosin, an enzyme used in cheese-making becomes the first product to be introduced into the food supply.
1990	The Human Genome Project is launched.
1990	The first human gene therapy trial is performed on a four year old girl with an immune disorder.
1991	The gene implicated in the inherited form of breast cancer is discovered.
1992	Techniques for testing embryos for inherited diseases are developed.
1994	First commercial approval by the US FDA of a transgenic plant, the Flavr-Savr tomato
1995	The first successful Xenotransplantation trial is conducted, transplanting a heart from a genetically engineered pig into a baboon.
1996	The first trial of gene therapy for a neurological disorder is conducted in NZ.
1996	NZ researchers complete the first linkage gene map of the sheep genome.
1996	'Dolly' the sheep is cloned from a cell from an adult sheep.
1996	NZ passes the Hazardous Substances and New Organisms (HSNO) Act. which controls the development and importation of GMO's.
1998	NZ researchers produce 'Elsie', a clone of 'Lady', the last of the Enderby cattle line,
1998	NZ researchers develop the first genetically engineered radiata pine.
1999	A US company announces the successful cloning of human embryonic cells from an adult skin cell.
1999	Chinese scientists clone a giant panda embryo.

(Source: 6)