biotechnology

Biotechnology is the use of living organisms or their components to generate a useful product or service. Biotechnology today is a massive field incorporating many different and complex scientific concepts and techniques. It can be as simple as the fermentation process carried out by microorganisms to produce wine or beer, or as complex as manipulating the DNA polymer using restriction enzymes to produce a desired protein.

Biotechnology encompasses such fields as:

- genetic engineering
- chemical engineering
- immunology
- cell biology
- biochemistry
- microbiology
- agricultural technology.

It can provide solutions to environmental problems, medical problems and food shortages. Biotechnology can be highly controversial when organisms are genetically altered to produce a new product. This includes working with enzymes, altering the genetic structure of a microbe to produce a vaccine, or the cloning of animals.

A timeline for the development of biotechnology

1750 BC The first beer is brewed.

500 BC The Chinese develop a crude antibiotic from soybeans.

100 AD The Chinese develop an insecticide from chrysanthemum flowers.
In modern times, pyrethrins have been isolated from the flower head of chrysanthemums and used to repel insects. They breakdown naturally in sunlight, which makes them an environmentally friendly product for farmers. It also means they only have

figure bt.1 The chrysanthemum flower contains a natural insecticide called pyrethrin.

a short life and constant resprays are necessary. Scientists have now developed pyrethroids based on the pyrethrin structure. These pyrethroids still repel and kill insects but last much longer. They are also rapidly broken down to harmless compounds when they reach the soil or if ingested by mammals.

1797 Jenner discovers that cowpox can be used as a vaccine for small pox.

1877 Koch develops a method for staining and identifying bacteria.

1914 Raw sewage is treated with bacteria in Manchester, England.

1925 The cactoblastis moth is introduced to Australia to kill the prickly pear.

figure bt.2 The prickly pear has been successfully controlled by the cactoblastis moth, which was introduced to Australia in 1925.

1928 The first antibiotic is discovered in mould by Alexander Fleming.

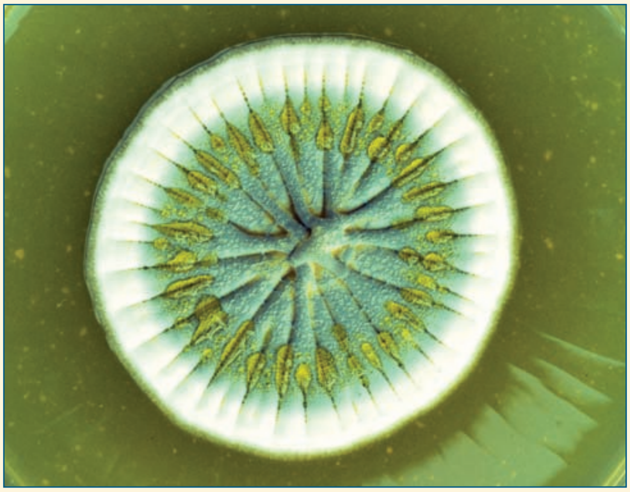

figure bt.3 The first antibiotic (penicillin) was extracted from a mould.

figure bt.4 The cane toad was introduced to control the cane beetle. It became an environmental disaster by growing to prolific numbers without any natural predators.

1935 The cane toad was introduced to Australia to eradicate the cane beetle.

1944 DNA is identified as the main component of genes.

1953 The double helix structure of DNA is uncovered by Watson and Crick.

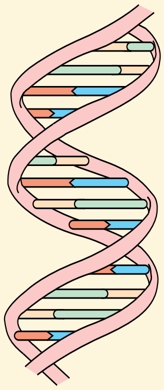

figure bt.5 The DNA double helix.

* Section 16.3 **Matter cycles** describes the chemistry of DNA (page 546).

1954 Techniques are developed that allow scientists to grow cells outside the body.

1969 An enzyme is created outside the body. Enzymes are biological catalysts and have some advantages over inorganic catalysts.

- They work at lower temperatures and pressures, making them more energy efficient.
- They do not require dangerous solvents.
- They are highly specific.
- They can be genetically modified for improved performance.
- They generally produce much faster reactions than inorganic catalysts.

However, they also have disadvantages.

- They cannot be reused like inorganic catalysts.
- They are sensitive to changes in pH and temperature.

Section 15.1 **Reaction speed** describes catalysts and their effects (page 514).

Enzymes have a wide variety of uses. Diabetics use an enzyme test strip to detect glucose level in their urine. These test strips contain a small coloured square that will respond to the presence of glucose by changing colour. The small square contains two enzymes, an indicator and a buffer. If glucose is present in the patient's urine, the enzyme glucose oxidase will act as a catalyst for the reaction between the glucose in urine and oxygen.

$$2C_6H_{12}O_6(aq) + 2O_2(g) \rightarrow 2C_6H_{11}O_7(aq) + H_2O_2(aq)$$

The hydrogen peroxide produced in this reaction oxidises the indicator, producing a colour change. The use of enzymes speeds up the two reactions. This means a test strip will reveal in seconds if glucose is present in the urine by producing a change in colour.

Enzymes are also used:

- in the manufacturing of bread, wine and cheese
- to remove cyanide ions which are present in the environment as a result of gold mining and extraction methods
- in the treatment of oil spills
- in the creation of stone washed jeans
- in the production of alcohol in beer
- in the manufacturing of washing powders, which contain lipases, proteases and amylases to assist in the breakdown of fats, proteins and carbohydrates that may have stained clothes.

Section 16.1 **Reactions of life** describes enzymes and how they work (page 532).

1973 Recombinant DNA is first used in bacteria by the scientists Cohen and Boyer. Recombinant DNA technology involves implanting the genes from one animal or plant into the cells of another—for example, placing a human gene into a bacterium.

1974 Monoclonal antibodies are developed. Monoclonal antibodies are manufactured outside the body and engineered to bind to and neutralise a specific protein. They can be used in the fight against cancer and other infections. They can also be used to detect pregnancy.

1977 The first human protein is created from bacteria that have been genetically modified.

1980 Patents are awarded for genetically modified life forms and gene cloning techniques.

1981 Gene manufacturing machines go online. Genetically modified plants are created.

1982 Human insulin is produced by genetically altering bacteria using recombinant DNA techniques. Previously diabetics injected pig insulin into their blood stream to maintain a healthy blood glucose level.

1983 An artificial chromosome is synthesised. A new technique for copying genes is discovered: PCR (polymerase chain reaction). The genes for some inherited diseases are identified.

figure bt.6 DNA fingerprinting can be used to place a person at the scene of a crime.

1984 DNA fingerprinting becomes possible. A genetically engineered vaccine is produced. The Nobel Prize for Chemistry is awarded to Professor Merrifield of Rockefeller University. Merrifield perfected an automated method for creating the protein insulin. He managed to link together 51 amino acids without the use of bacteria.

Merrifield overcame several problems to synthesise insulin in the laboratory. Biochemists can now design polymers by linking specific amino acids together to form designer proteins.

* Section 16.2 **The chemistry of digestion** describes amino acids and the structure of proteins (page 534).

1986 Field experiments begin on genetically altered tobacco plants. The first genetically engineered vaccine for humans is approved (the hepatitis B vaccine). The hepatitis B vaccine is a synthesised protein copy of the real hepatitis virus.

1987 Genetically modified bacteria that prevent frost formation on plants are approved for field-testing.

1989 The gene that causes cystic fibrosis is isolated.
Oil-digesting bacteria have been developed that can be used to neutralise oil spills.

1990 Gene therapy for inherited disorders is approved.

1991 Genetically engineered biocontrol agents go on sale.

1992 The genetically engineered Factor 8, a clotting agent, is approved for use on hemophiliacs. Hemophiliacs lack the ability to form clots and can bleed to death internally from a simple bruise. Factor 8 can be administered at a hospital to prevent this.

1994 Tomatoes are genetically altered to slow down the ripening process, making them easier to transport without spoilage.

1995 The entire gene sequence of a bacterium is uncovered.
The calicivirus, designed to kill rabbits (which have become a pest in Australia), is accidentally released.

1996 Scientists in Scotland clone sheep.
Genetically engineered interferon is approved for treatment of multiple sclerosis.

1998 Techniques to regenerate human tissues are developed using stem cells from human embryos. Scientists hope that future development of this technology may result in the generation of new nerves for paralysis victims or new cartilage to replace worn joints.

2000 Pigs are cloned.

2001 The entire human genome is mapped and published.

figure bt.7 It took 277 attempts to clone Dolly successfully. Dolly developed arthritis at an unusually young age and scientists are trying to determine if the cloning techniques were responsible.

Biotechnology for the next milennium

Biotechnology today

Today biotechnology is used for a wide range of purposes.

- Biosensors are used to monitor food industries and detect chemicals in the environment.
- New and more powerful antibiotics are being created.
- Bacteria are used to produce biopolymers, which can be used as plastics. They are extremely effective and biodegradable, but currently cost ten times as much as their synthetic competition.
- Caterpillar-resistant cabbages have been created by genetically incorporating the gene for scorpion poison into the cabbage. It exudes the poison in the form of a sap, which means insecticides are not required.
- Scientists are experimenting with genetically modifying the compounds found in spider webs to produce a biosteel.
- Salt-loving plants are being developed for Australian soils to cope with our salinity problems.

figure bt.8 The benefits of salt-tolerant crops are very relevant to Australian farmers. The plant on the right was genetically modified to cope with salt-affected soils.

Biotechnology tomorrow

There is no question that biotechnology is providing some fantastic benefits to the world community, but what is the downside? What if it is possible for genes from a genetically modified plant to become incorporated into other plants or animals by accident? Cloning and embryonic stem cell research is causing all sorts of moral and ethical debates. Could a genetically altered smallpox virus be created that could then be used as a terrifying bioweapon?

Scientists, doctors, judges, politicians and the community must make some careful decisions that weigh up the benefits and the risks each new biotechnological breakthrough brings. What is your opinion?

Consider this

1 Read the magazine article below and answer the following questions.

Engineered enzyme washes whiter than white

DURING THE next year, people in Europe should be able to buy washing powder containing an enzyme that can break down fats. Until now, no one has developed a commercially available enzyme that will break down fats.

The new enzyme, Lipolase, is genetically engineered by the world's largest producer of industrial enzymes, a Danish company called Novo-Nordisk. The company … claims that Lipolase is the first widely available industrial enzyme to have been produced by genetic engineering. Within five years the company plans to make all its industrial enzymes using the techniques of genetic engineering …

In its hunt for a suitable enzyme, Novo-Nordisk investigated a range of enzymes called lipases … Molecular biologists at the company identified a fungus which will produce a specific type of lipase that is good at breaking down the fats found in human foods.

Although … the fungi produce these useful lipases naturally, they do not produce enough to be financially viable. So the geneticists identified the sequence of nitrogen bases which make up the DNA of the fungus and cloned that sequence. They then spliced the section of the DNA which holds the gene that codes for the lipase into a new host organism, a … fungus. [They] found that it will produce the lipase in sufficient quantities.

Novo complains bitterly at the length of time it has had to wait for a licence to produce Lipolase in Denmark … The same process took only four weeks in Japan.

a This article reflects current research in the development of enzymes for commercial use. What are the advantages of enzymes compared to inorganic catalysts?

b What tests would you require the Novo-Nordisk company to perform on the enzyme Lipolase before it was released commercially?

c Why might governments be cautious about licensing the use of genetically engineered organisms to produce enzymes? Discuss the issues involved in this question with other class members.

Further investigations

1. One of the first biotechnical breakthroughs was the production of alcoholic beverages using yeast. Investigate the chemistry of the fermentation processes. Include in your investigations the details of anaerobic fermentation and malolactic fermentation.
2. Enzymes are extremely sensitive molecules that require specific conditions to operate efficiently. Investigate the effects of enzyme concentration, substrate concentration, temperature and acidity on the efficiency of the enzyme performance. In your answer, use graphs to compare enzyme activity to a progressive change in each of these conditions.

Experimental investigations

The pictures on a photo negative are produced by silver halide crystals held together by a protein called gelatin. If gelatin is broken down or removed, the picture will disappear. Design an experiment that would compare the effectiveness of an enzyme-based washing powder and a non-enzyme based powder using some negatives, a hot water bath, some boiling tubes and a stopwatch.