From Babylon to BIOTECHNOLOGY

Science content

Fermentation, microbes, enzymes, antibiotics, penicillin, DNA, genetic engineering, enzymes in washing powder.

Science curriculum links
AT3 Processes of life
AT4 Genetics and evolution
AT7 Making new materials
AT17 The nature of science

Syllabus links
- GCSE Science, Biology, Chemistry
- Sixth-form General Studies

Cross-curricular themes
- Health Education
- Economic Awareness

Lesson time
1–2 hours

Links with other SATIS materials
102 Food from Fungus
201 Energy from Biomass
309 Microbes make Human Insulin
609 Hitting the Target
1010 Can it be done? (questions 23, 29)
1202 Mapping the Human Genome

NERIS
Search on
BIOTECHNOLOGY
and UPPER SECONDARY
Additional search terms
GENETIC ENGINEERING
ENZYMES

SUMMARY

This unit was developed from SATIS No. 710, *What is Biotechnology*?. The new unit, *From Babylon to Biotechnology,* replaces the former unit with the exception of case study 2, *Using bacteria to extract metals from ores*. This case study remains up-to-date and may be used with the new unit.

The new unit provides a similar introduction to the historical development of biotechnology and to current concerns. The emphasis has been changed, especially on pages 3 and 4 and more questions added. There is a new case study about enzyme washing powders.

STUDENT ACTIVITIES

- ☐ Reading and answering questions: the development of biotechnology.
- ☐ Case study – reading, data interpretation and questions: *Enzymes in the washing machine.*

AIMS

- ☐ To show the development of an important branch of science
- ☐ To give a simple introduction to biotechnology and illustrate its wide scope
- ☐ To illustrate how biotechnology can be used to meet some human needs
- ☐ To provide practice in comprehension and data interpretation skills

USING AND ADAPTING THE UNIT

- ☐ The unit is suitable for class or independent use.
- ☐ The unit may be used in parts and combined with case study 2 from SATIS No. 710.
- ☐ The information in the case study, *Enzymes in the washing machine,* could be used as a starting point for practical investigations. The new lipase, Novo Lipolase 100T is available from The National Centre for Biotechnology Education, Department of Microbiology, University of Reading. Tel. 0734 873743. Amongst its many activities, the Centre provides advice and publishes a newsletter for schools.

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Developed from SATIS No. 710, *What is Biotechnology?* (1986).

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What is biotechnology?

Q1 *Traditional uses of biotechnology mentioned in the unit are making beer, bread, wine, vinegar, yoghurt and cheese.*

Q2 *A beer-like drink may have been made by accidental fermentation of a cereal-water mixture.*

Q3 *The microscope*

Q4 *Pasteurisation*

Q5 *Living organisms maintain temperatures around 37 °C because their enzymes function at this temperature. However, there are enzymes which can tolerate much higher temperatures and the alkaline conditions produced by washing powders.*

Q6 *(a) Antibiotic (b) Recycled from patients' urine*

Q7 *DNA (deoxyribonucleic acid).*

Q8 *6000 BC Brewing beer*
4000 BC Yeast as a raising agent
BC wine making, yoghurt, cheese
1600s Microbes discovered
1800s Pasteurisation
1897 Edward Buchner – enzymes
1928 Penicillin discovered
1940s Penicillin made in bulk
1953 DNA structure discovered
1960s Genetic code cracked
1970s Genetic engineering

Q9 *Examples of biotechnology are (b), (c), (e) and (f).*

Products containing enzymes are widely available. For example, well-known washing powders and barbecue sauces contain proteases to break down proteins (which in the case of barbecue sauce will make meat tender) and toothpastes contain enzymes also found in saliva (such as lactoperoxidase) that protect against tooth decay. The enzyme described in part B is not yet available in washing powders. It is in fact a lipase (lipolase), but its name has not been given in the student text to avoid confusing students.

Enzymes in the washing machine

1 *Using saliva*

2 *It contains enzymes (such as amylase)*

3 *'Biological' washing powders contain enzymes.*

4 *Proteases in washing powder solutions gradually break down other enzymes such as lipases. This is a particular problem with modern liquid formulations. However, it can be overcome by adding an enzyme inhibitor (boric acid) to the liquid. In the washing machine, the boric acid is diluted and so loses its inhibitory effect.*

5 *(a) The activity increases (non-linearly) with increasing pH (and nears 100% at pH 11).*
(b) pH 7
(c) More effective in alkaline solution.
(d) About 64%
(e) 9–10.5

6 *(a) The activity rises from 60% between 10 and 37 °C to peak at 100% and falls with increasing temperature thereafter.*

(b) The 40 °C setting of a washing machine. (The graph shows an optimum value of 37 °C.)

7 *(a) C*
(b) C was launched at a time of concern that enzymes might be harmful. Any skin allergies were likely to be blamed on the new powder.
(c) The number of complaints has fallen to a very low value and there is no significant difference between non-biological and biological powders A and B.
(d) No. They show no difference.

Despite many years of research, there is no evidence of allergies to enzymes occurring amongst domestic users of biological washing powders. (The same is not true of the other components of washing powders.) Most of the complaints seem to be inspired by fears aroused by the media. Workers in detergent manufacturing plants did suffer when enzymes were first introduced, but this problem was quickly overcome by the introduction of stringent safety regulations and the development of effective encapsulation techniques to prevent the formation of airborne enzyme dust.

Acknowledgements
We wish to thank the National Centre for Biotechnology Education for their help in producing this unit.
Illustrations by Joyce Curtis
Figure 3 supplied by J Sainsbury Plc.

From Babylon to BIOTECHNOLOGY

Part A – What is biotechnology?

Part A Information and questions.
Part B Case study of a washing powder enzyme.

Biology is the study of living things. Technology is about solving problems to provide the things we need. So biotechnology uses living things to make and do the things we need.

More precisely, **biotechnology is the use of biological processes to provide goods and services.** These goods include chemicals, foods, fuels and medicines. Services which depend on biotechnology include waste treatment and pollution control.

Biotechnology uses living cells or chemicals such as enzymes made by them. The cells may come from familiar plants or animals or be microbes, like yeast.

Milestones in biotechnology

6000 BC: the first beer is brewed

Traditional biotechnology started before 6000 BC when the Babylonians brewed the first beer. Brewing uses yeast cells to turn sugar to alcohol. About 4000 BC, the Egyptians learnt to use yeast in bread-making. Wine is made by fermenting grapes and is mentioned in the Old Testament of the Bible.

Beer, bread and wine all depend on the fact that yeast cells can live without oxygen. They produce carbon dioxide and alcohol in a process called **anaerobic fermentation.**

Another ancient fermentation process uses bacteria to turn alcohol to acetic acid in the manufacture of vinegar. Yoghurt is also made by fermentation. Bacteria which make lactic acid are added to milk. Many types of bacteria and moulds are used to convert milk into different cheeses.

All this traditional biotechnology was an art, rather than a science. People did not understand what was going on when they made beer, bread or cheese. Before biotechnology could really take off, scientists had to find out more by carrying out careful investigations.

Figure 1 The Babylonians were some of the earliest people to use biotechnology

Q1 *Give three examples of traditional uses of biotechnology.*

Q2 *How do you think the Babylonians discovered beer making?*

Seventeenth century: microbes discovered

Microbes were used in making food and drink for thousands of years before they were identified. It was not until the seventeenth century that Anton van Leeuwenhoek reported seeing microbes with one of the first microscopes.

At the time many people thought that living things could grow of their own accord from non-living things. In the nineteenth century Louis Pasteur disproved this idea which was called the theory of spontaneous generation. He showed that microbes could only come from other microbes. Later, Pasteur used his ideas to prevent wine turning to vinegar and milk from going sour. His method is still used today, and is called pasteurisation.

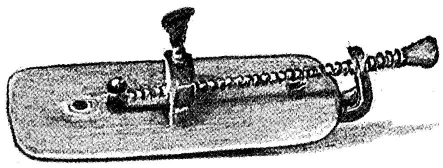


Figure 2 Leeuwenhoek's microscope

> *Q3 What invention was vital before microbes could be discovered?*
>
> *Q4 Milk for sale to the public has been heat treated and rapidly cooled which kills most of the microbes that may be in it. What is the process called?*

1897: enzymes are discovered

In 1897 Edward Buchner showed that you do not need whole yeast cells to make alcohol. Parts of the cells will do the job. We now know these are the parts which contain enzymes.

Enzymes are biological catalysts. They are made by cells to speed up and control biological reactions. Enzymes are present inside the cells of all living things. They control all life processes. Since 1897 many useful enzymes have been obtained from the cells of microbes, plants and animals.

Enzymes are used in industry and in the home in things as different as biological washing powders and barbecue sauce.

Figure 3 Biological washing powders contain enzymes which break down protein stains

> *Q5 Suggest why a lot of living things have body temperatures around 37 °C*

1928: penicillin – biotechnology makes the wonder drug

In the early years of this century a scratch or cut which went septic could spell death. People born in 1930 could on average expect to live until they were 54. Today, our life expectancy is much greater. At least ten years of this extra life span are due to the use of antibiotics.

In 1928, Alexander Fleming, a doctor at a London hospital, made an interesting observation. He noticed that a certain mould, *Penicillium*, stopped bacteria from growing. Some years later, scientists in Oxford extracted a chemical from the mould, and used it to fight bacterial infection. This chemical was called penicillin.

Penicillin was at first made in large amounts by growing the mould on nutrient broth in thousands of milk bottles. Technologists in America then developed better ways of culturing the mould inside large fermenters.

Penicillin saved many Allied lives during the Second World War. In fact the drug was so precious that urine from treated patients was collected. The penicillin excreted in it was separated out and used to treat others. The Nazis did not have penicillin, and had to rely upon older, less effective drugs.

Since then, many more antibiotics have been discovered. Most are made using some form of biotechnology.

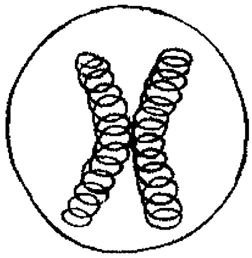
1953: DNA – the code of life

Why do people look like their parents? Why is it that cats give birth to little cats, and not to dogs or rabbits? Questions like this have puzzled scientists for hundreds of years.

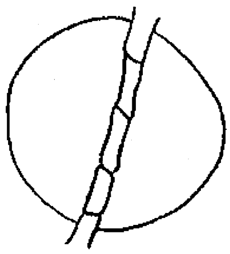
In 1953, scientists in England called Rosalind Franklin, Maurice Wilkins, James Watson and Francis Crick put together the evidence and provided part of the answer. The molecule they were working on was deoxyribonucleic acid, known as DNA. Rosalind Franklin discovered it had a spiral shape and with the help of a home-made model, Watson and Crick worked out the structure.

DNA is found in the chromosomes within the cells of all living things. It controls the cells' activities. DNA is carried in sperm and eggs, and so is passed on from one generation to the next. Copies of it go into each new cell when the cell divides. This explains why we look like our parents.

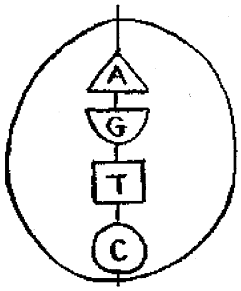
The DNA acts as a set of coded instructions for the cell. Instructions for making proteins are called **genes.** Once the structure of DNA was known, people began trying to crack the genetic code. By the early 1960s, they had succeeded. The genetic code turned out to be the same in all living things. This meant, in theory, that you could take instructions from one cell and stick them into another – even if the cells came from completely different organisms. This process of 'cutting and pasting' DNA is called **genetic engineering**.



A chromosome



Genes on a chromosome



DNA

Figure 4 Chromosomes and DNA

Q6 *(a) What sort of drug can be used to fight an infection caused by bacteria?*
(b) How was penicillin recycled during the Second World War?

Q7 *Name the molecule that contains the genetic code.*

1970s: genetic engineering is developed

In genetic engineering, scientists move DNA instructions from one type of cell to another. This can prompt cells to make useful products.

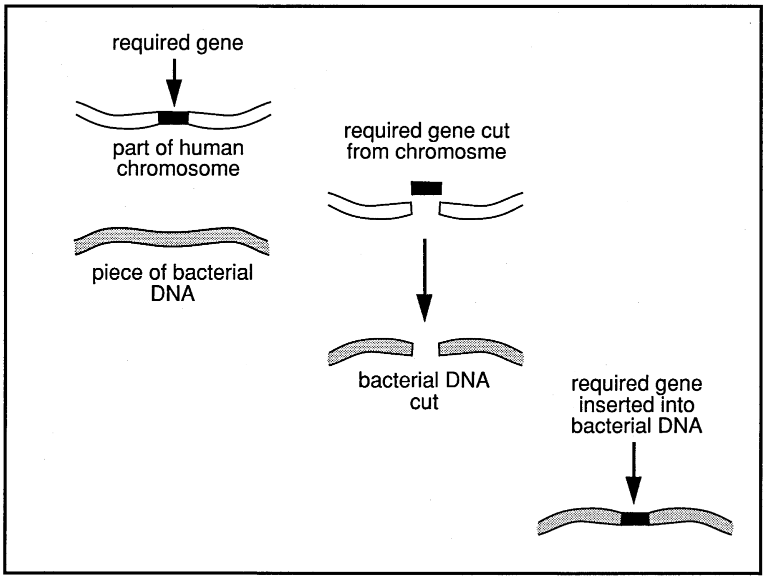
A child who does not produce enough growth hormone remains relatively short. Nowadays this can be prevented by treating the child with human growth hormone. Before genetic engineering, the hormone had to be extracted from dead bodies. It took 20 000 bodies a year to get enough hormone to treat all the people in Britain who needed it. Now DNA from human cells is put into microbes. In a fermenter the size of a dustbin the microbes make the same amount of hormone in 12 hours.

Other products of genetic engineering include insulin, which is needed by people with diabetes and vegetarian rennet for making cheese. Vegetarian rennet is used instead of rennet taken from calves.

Q8 Make a time chart listing the important events in the development of biotechnology described in this unit.

Q9 Which are examples of biotechnology?
- *(a) Extracting human growth hormone from dead bodies*
- *(b) Making human growth hormone by fermentation*
- *(c) Producing compost from rotting plant matter*
- *(d) Refining oil to make petrol, diesel fuel, fuel oil, etc.*
- *(e) Using bacteria to turn glucose to fructose (a very sweet sugar)*
- *(f) Making biogas from decomposing household and farm waste*
- *(g) Making steel from iron*

Figure 5 Genetic engineering – the basic method



Who are the biotechnologists?

The biotechnology industry needs all sorts of people working together as a team. Microbiologists, biochemists, computer scientists and engineers use scientific discoveries to produce new or better goods and services. Biotechnology companies also need lawyers, accountants and sales staff who understand something about the science behind the business.

Biotechnology could help to solve many of the world's problems, such as disease, hunger and pollution. However, it also raises many difficult and controversial issues. It is important that we all know about biotechnology so that we can help to decide what should and should not be done.

Part B – Enzymes in the washing machine

In 1821 the US Army Regulations told soldiers to clean their uniforms in an unusual way:

> "... spots of dirt or grease, or stains (on the uniform), will be taken out by ... saliva"

Saliva contains enzymes such as salivary amylase which normally help us to digest our food. Proteins, fats and starch are common in the stains found on clothes. These substances can also act as a kind of glue, sticking dirt to the fabric. Enzymes help to break down these stains in the same way that enzymes break down food in our bodies.

Enzymes are not themselves alive, but come from living things. The enzymes in washing powders come from harmless microbes. The idea of putting enzymes into washing powders didn't catch on until a method of growing large numbers of microbes in fermenters was developed. Washing powders containing enzymes are often called 'biological'.

When biological powders were first introduced, manufacturers received many complaints. People blamed enzymes for skin rashes and itching. They believed that protein-digesting enzymes (proteases) in the powders were responsible. However, after years of careful research there is no scientific evidence for this.

Because enzymes usually work at low temperatures they can help to shift stains without the need for very hot water or harmful chemicals. Enzymes are biodegradable – once they are washed down the drain they break up within a few hours.

Most biological powders contain proteases – protein digesting enzymes. But proteins aren't the only stains on clothes. Danish biotechnologists have now made a new enzyme for washing powders, using the techniques of genetic engineering. The new enzyme breaks down fats, which make the worst kind of stains. Scientists took the gene for a fat-digesting enzyme (a lipase) from one fungus and put it into another fungus called *Aspergillus*. They chose *Aspergillus* because they already have a lot of experience of growing it in fermenters.

The new lipase enzyme can break down grease and oils. It will remove marks like shoe polish, lipstick and chip fat from fabric.

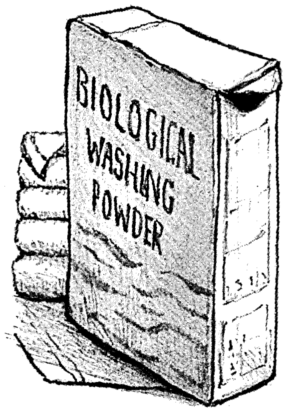


Figure 6 Instead of washing clothes in very hot water, biological washing powders will help to break down stains in low temperature washing programs

1 How were US soldiers ordered to get spots of dirt off their uniform in 1821?

2 Why did the method work?

3 Why are some washing powders described as 'biological'?

4 Enzymes are proteins. What might happen if washing powder manufacturers put a mixture of proteases (protein-digesting enzymes) and lipases (fat-digesting enzymes) into the same product?

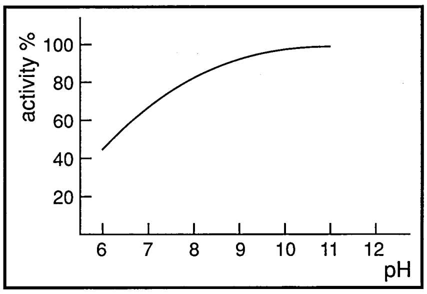


Figure 7 Activity of the new lipase enzyme at different pH values

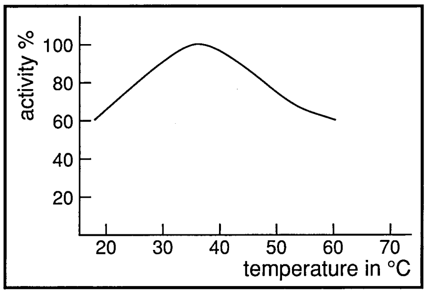


Figure 8 Activity of the new lipase enzyme at different temperatures

The graphs in figures 7 and 8 show how the *activity* of a new lipase enzyme depends on pH and temperature.

5 Look at figure 7.

(a) Describe how the activity of the enzyme varies with pH.

(b) What is the pH of a neutral solution?

(c) Is the new enzyme more effective in acid or alkaline solutions?

(d) Use the graph to find the activity of the new enzyme in a neutral solution.

(e) Strong acids and alkalis are corrosive. What pH would you recommend for a washing powder that contains this enzyme?

6 Look at figure 8.

(a) Describe how the activity of the new enzyme varies with temperature.

(b) What temperature would you advise for washing clothes in a washing powder containing the new enzyme?

The graphs in figure 9 show the number of complaints received after three new washing powders, A, B and C, were introduced. (Most complaints were about allergies like skin rashes and itching.)

Washing powder A was non-biological; washing powder B was biological; washing powder C was biological and similar to B, but was launched when newspapers announced that enzymes might be harmful.

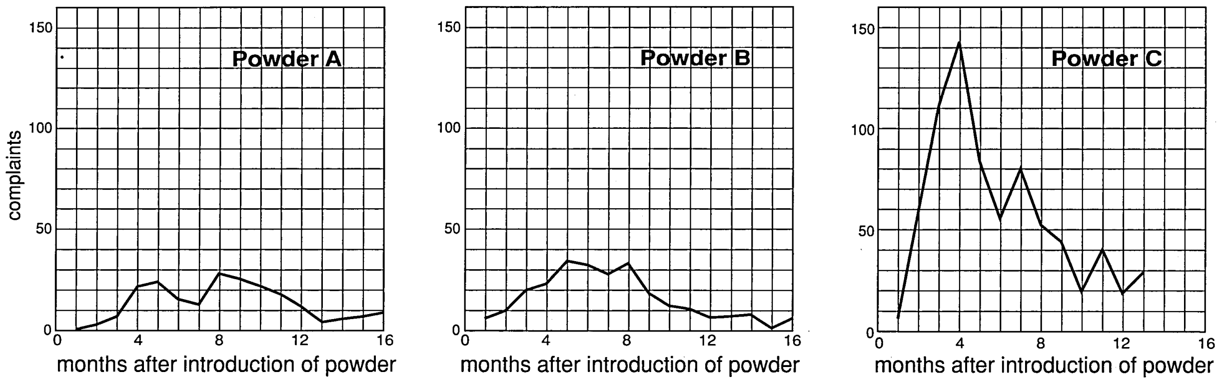


Figure 9 The number of complaints received after three new washing powders, A, B and C, were introduced

7 Look at figure 9.

(a) Which powder received the most complaints?

(b) Powders B and C are very similar. Suggest why one received more complaints than the other.

(c) What can you say about the number of complaints after the powders had been on sale for more than a year?

(d) Do these graphs give evidence that enzyme washing powders cause skin rashes and itching?

Answers to the questions are given in the *Teachers' Notes.*