Microbes make Human Insulin

Contents: Reading, questions and discussion on the use of genetic engineering techniques to produce human insulin.

Time: 1 to 2 periods depending upon the extent of discussion.

Intended use: GCSE Biology and Integrated Science. Links with work on hormones, insulin, microbiology and genetics.

Aims:

- To complement work on hormones, microbiology and genetics
- To develop awareness of the problems experienced by diabetics
- To develop awareness of the issue of 'prevention verses cure' in relation to diabetes
- To show the principles of the technique of genetic engineering
- To provide opportunities to practise skills in reading and comprehension.

Requirements: Students' worksheets No. 309.

This unit looks at genetic engineering in relation to a recent technological breakthrough resulting in an improved form of insulin being available for the treatment of diabetes. Students are encouraged to consider a number of issues related to insulin and diabetics as well as genetic engineering.

Notes on questions 5 and 6

Q.5 Insulin from slaughtered animals (pigs and cattle) has a slightly different structure from human insulin. It is interesting to note that another recent development in biotechnology is an enzymic process for changing pig insulin to human insulin. There is market competition between the two large companies which produce human insulin by different methods.

Q.6 Most current applications of genetic engineering are in the pharmaceutical field — for example, in the production of interferon and antibiotics.

Further resources

Further information on diabetes can be obtained from: British Diabetic Association, 10 Queen Anne Street, London W1M 0BD.

Human Insulin from Recombinant DNA Technology is a well-presented booklet with background information, including photographs and a useful glossary. For teachers, but may also be useful for more academic students. Available from: Public Relations Manager, Lilly Industries Ltd, Kingsclere Road, Basingstoke, Hants.

Acknowledgement Figure 2 supplied by British Diabetic Association.

MICROBES MAKE HUMAN INSULIN

The first humans ever to receive a material made by 'genetic engineering' were a group of volunteers at a London hospital in 1980. They were injected with human insulin which had been made by microbes. By 1982 this insulin was in general use. But why is insulin so important, and what is 'genetic engineering'?

The importance of insulin

After eating and digesting a meal, sugars, particularly glucose, pass into the bloodstream. Normally, this extra glucose is stored in the liver as a substance called glycogen, and as fat. When the body needs glucose for energy, the stored glycogen is broken down to give glucose again (Figure 1).

Insulin is the hormone which controls the level of glucose in the blood. It is made in the pancreas. From the pancreas it passes in the bloodstream to the liver. Insulin controls the conversion of glucose to glycogen in the liver. If people do not produce enough insulin they cannot store glucose. Some glucose is lost in the urine. This happens in at least one type of **diabetes**.

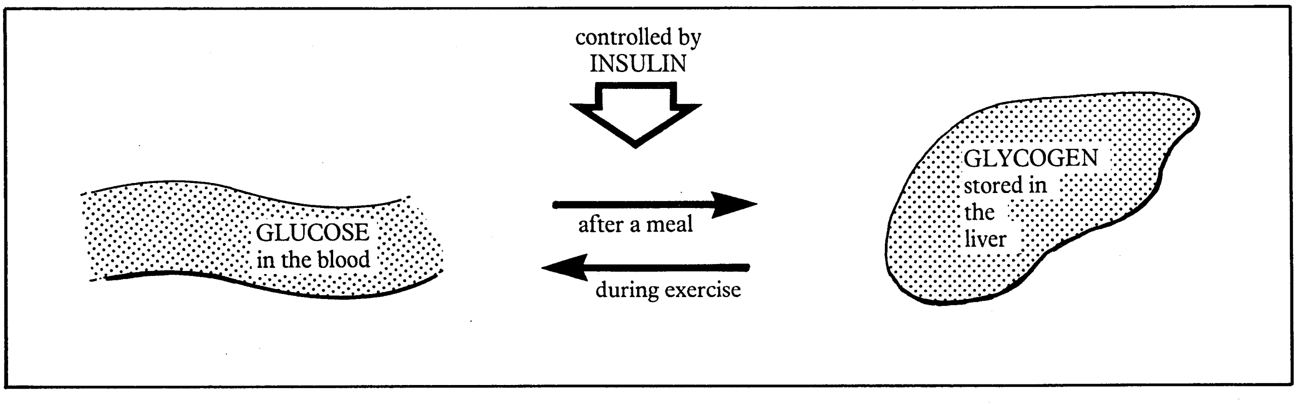

Figure 1 Insulin controls the level of sugar in the blood

Diabetics must follow a carefully controlled diet. They may also need regular injections of insulin. Without insulin, diabetics may become weak and sleepy. They lose weight, and eventually might die, but with insulin they can lead relatively normal lives. Even with treatment, diabetes may cause damage to the eyes, heart and circulatory system in some cases.

Diabetes is the third largest killer in the developed world. At present there are 600 000 diabetics in Britain and 250 000 of these need insulin daily.

The disease is also on the increase. Like heart disease, high blood-pressure and overweight (often called 'Western diseases'), diabetes has become much more common as people's diets have changed. In rich western countries like Britain and the USA, people eat a lot of fat and sugar, and not much fibre. It is thought this may cause some people to suffer from diabetes.

With diabetes on the increase, insulin is needed in larger quantities. Until recently insulin was obtained by purifying insulin from slaughtered pigs or cattle. This animal insulin is slightly different from human insulin. This traditional supply may not be enough for the increasing number of diabetics who require it. And insulin is a valuable product: a daily dose costs about £3 per person.

Answer questions 1 to 3.

Questions

1. *If everyone had a low fat, low sugar, high fibre diet, would diabetes disappear?*
2. *In recent years many people in developing countries have moved from the countryside to live in the towns. This has resulted in a change of life-style. In what ways may their life-style change? What effect could such change have on the number of diabetics in these countries?*
3. *Why must insulin be injected, rather than taken orally? (Remember, insulin is a protein.)*

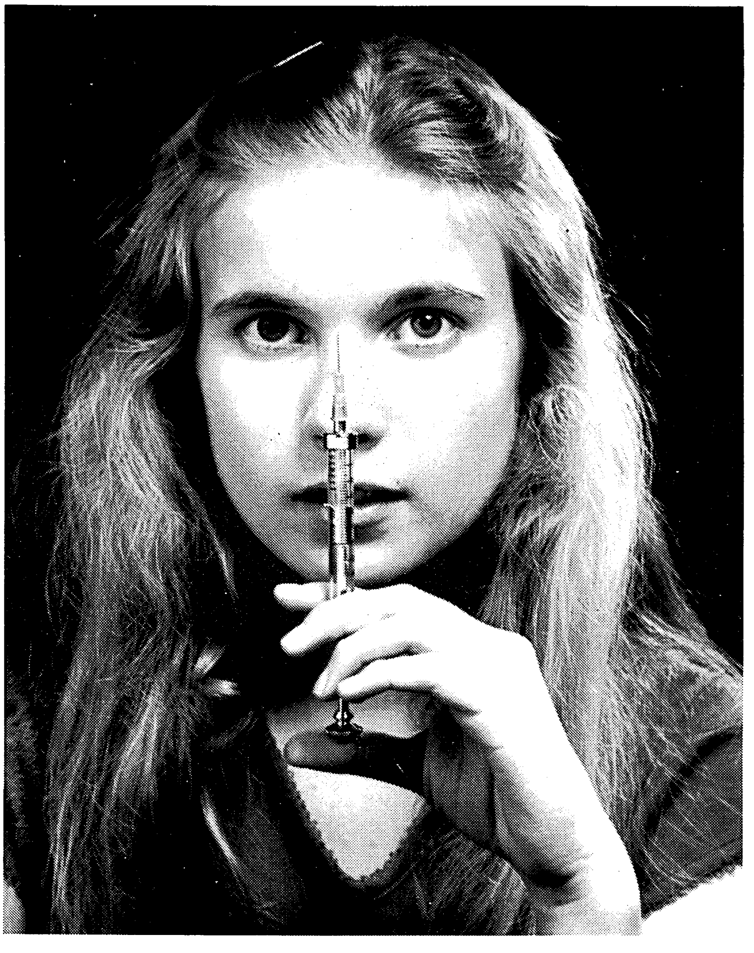

Figure 2 A diabetic girl with her lifeline

What is genetic engineering?

Genetic engineering is a specialized technique which has been in use since 1973. As a result of the technique some cells can be given the information to produce substances they would not normally make.

When living things breed, characteristics, such as eye colour, are passed on from one generation to the next. These characteristics are controlled by **genes**, found in the nuclei of all cells. They are made up of a chemical called **DNA**. Many genes are arranged together to form threads called **chromosomes**. Genes control how living things work, what they look like and what chemicals, such as enzymes or hormones, they can make. Insulin is such a hormone. A certain human gene is responsible for producing insulin, which is a protein.

Genetic engineering usually involves taking a gene from a human cell and putting it in a cell of a microbe. Figure 3 shows the method. First the gene that is needed must be searched for and found on the human chromosome. As genes are very small this is difficult. It is done using special enzymes which act as 'chemical scissors' to cut the gene from the chromosome. Next a piece of DNA in a microbe cell is cut. Other special enzymes are then used to put the human gene into the microbial DNA.

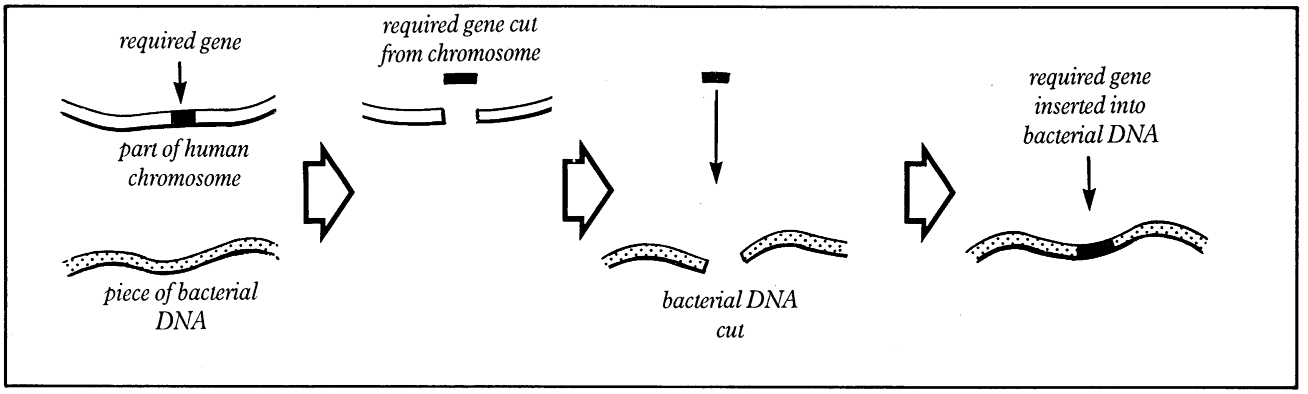

Figure 3 Genetic engineering puts a human gene into a piece of bacterial DNA

The human gene causes the microbe to make a new material, which it previously did not produce. Under suitable conditions microbes divide quickly, so that a lot of this new product can be made in a short time. In this way the gene controlling human insulin production can be put into a bacterial cell, so that the microbe can make human insulin.

Answer questions 4 to 6.

Microbes make human insulin

During the early 1980s genetic engineering was used to 'teach' certain microbes to make human insulin.

But could this new human insulin have long-term side-effects? Has scientific discovery in the form of genetic engineering provided *the* answer — or is it just one of the alternatives? Who will gain most benefit — the diabetics or the companies making insulin? Could this useful technique result in the formation of 'new superbugs' which will cause disease and havoc, rather than improve health? It is thought not, but these are some of the questions which scientists involved with genetic engineering have been asking in recent years.

Questions

4 *Hygiene is very important in any factory producing 'insulin from microbes'. Explain why.*

5 *In what way might human insulin from microbes be better than insulin from slaughtered animals?*

6 *The genetic engineering techniques described here were first used on a 'test-tube scale' in the laboratory. What has to be done before these techniques can be used to produce insulin in large quantities?*

Points for discussion

You might like to discuss these points in groups of three or four.

- Before large companies develop techniques for production they must have a suitable market. Why do you think insulin was the first product from genetic engineering to be made available to the general public?
- Before 'insulin from microbes' became available, diabetics who were vegetarians faced a difficult choice. What was this choice, and why has 'insulin from microbes' helped?
- One possible solution to the diabetes problem would be to put the gene for insulin production directly into the cells of people suffering from diabetes. Would this be (a) realistic (b) desirable?
- Genetic engineering has enormous possibilities. Discuss some other ways it might be used to the benefit of humans.
- Can you see any possible dangers in the future use of genetic engineering?

Recycling Aluminium

Contents: A home survey investigating the extent to which households consume aluminium, leading to a discussion of the question of recycling aluminium.

Time: Homework plus 2 periods or more, depending on amount of discussion.

Intended use: GCSE Chemistry and Integrated Science. Links with work on the manufacture, properties and uses of aluminium.

Aims:

- To complement work on aluminium
- To develop awareness of the opportunities and problems involved in the recycling of materials, in particular aluminium
- To show some aspects of the economics of aluminium production and fabrication
- To provide opportunities to practise skills in the collection and handling of data.

Requirements: Students' worksheets No. 310. Balance, accurate to 0.01g. Aluminium foil, scissors, 10 clean milk bottle tops.

A week will be needed for the survey to be carried out at home. The follow-up calculations could be done at home or in class. Less able students will probably need some help with the calculations.

The questions are best answered and discussed in class, perhaps in small groups, though they could be done for homework.

Notes on the survey and estimation of mass of aluminium used

Milk bottle tops are manufactured to a consistent thickness of about 0.025mm. One top weighs about 0.25g, though students should do this measurement themselves, preferably by weighing a number of milk bottle tops to get an average mass.

The thickness of household foil varies from about 0.018mm to about 0.014mm. 100cm^2 weighs about 0.4g, though students should make this measurement themselves.

Notes on some of the questions

Q.1 Apart from wrapping foil and bottle tops, many families will use aluminium foil dishes for pies, cakes, tarts, etc.

Q.2 Not much aluminium foil is recycled, because of the difficulty of collecting. Some milk bottle tops are recycled.

Qs 3 to 9 The idea of these questions is to bring out the importance of recycling non-renewable resources, and some of the difficulties involved in recycling. The advantages of recycling are many, in particular the conservation of non-renewable resources and the avoidance of waste disposal problems. But several factors combine to make recycling difficult in practice. The crucial factor is the problem of collecting waste metal and keeping it separate from other waste. Other important factors are the cost of melting and purifying the recycled metal, and the intrinsic value of the metal itself.

Notes on further questions and activities

The price of aluminium
Calculations will show that aluminium foil is a great deal more expensive than the metal direct from the factory. The difference can be attributed to fabrication costs for foil, and the cost of packaging, transporting, and marketing the foil.

The cost of electricity in aluminium manufacture
This difficult calculation is intended only for the most able students. It shows the high cost of the electricity needed to produce aluminium. Other factors contributing to the cost of the metal include labour costs, transport costs and the cost of mining and purifying bauxite.

Further resources

Siting an aluminium plant (DALCO) is a computer simulation which enables students to consider some of the factors to be considered when planning the siting and production targets of an aluminium smelting plant. Available from: Micro Software Unit, Longman Group, Burnt Mill, Harlow, Essex CM20 2JE.

Aluminium is a programme in the Granada Television series *Chemistry in Action.* It can be recorded off-air for school use. See ITV for Schools annual programme booklet for transmission times.

Acknowledgement Figure 1 supplied by British Alcan Aluminium Ltd.

RECYCLING ALUMINIUM

Aluminium is obtained from the mineral bauxite. Bauxite is impure aluminium oxide. At present, we know that there is enough bauxite to provide all the aluminium we need for about thirty years. This assumes that our use of aluminium continues at the present rate.

With this in mind, it is worth thinking about how we could save our reserves of aluminium. Two ways in which many of us waste aluminium is in milk bottle tops and in aluminium foil.

In this unit you will try to:

- Estimate how much aluminium we use each year in Britain for milk bottle tops and aluminium foil
- Look at the savings that we could make by recycling aluminium used in our homes.

Figure 1 Passing coiled aluminium sheet through rollers to reduce it to the required thickness for foil.

What you do

A Estimate the number of milk bottle tops your family uses each week.

B Estimate the area of aluminium foil (in square centimetres) which your family uses each week for cooking, wrapping food, etc.

One way of doing this is as follows:

(i) Find out approximately how often, on average, your family buys a roll of aluminium foil

(ii) Work out the area of aluminium foil in a roll (you can do this using the length and width of the foil, which are marked on the packet)

(iii) From (i) and (ii), work out the area of foil used in a week.

C Find the mass of a milk bottle top. The most accurate way of doing this is to weigh ten tops, then work out the mass of a single one.

D Weigh a piece of aluminium foil $100cm^2$ in area.

E Use your answers to **A** and **C** to work out the mass of aluminium your family uses each week in milk bottle tops.

F Use your answers to **B** and **D** to work out the mass of aluminium your family uses each week in foil.

G Collect results from the rest of the class. Find an average value for the mass of aluminium used per family per week in milk bottle tops and foil.

H Estimate the number of families in Britain. (The population of Britain is 55 million.)

I Using your answers to **G** and **H**, estimate the total mass of aluminium milk bottle tops and foil used in Britain:
(i) per week (ii) per year.

Questions to answer and discuss

1 *What other consumable forms of aluminium are used by your family? ('Consumable' means the aluminium is used once and thrown away. Do not include non-consumable aluminium articles like saucepans and bicycle frames.)*

2 *How much of the aluminium in your survey gets recycled? Do you know of any families which collect and recycle aluminium?*

3 *Work out the* cost *of the total mass of aluminium in the milk bottle tops and foil you estimate are used each year in Britain. (In 1985, aluminium cost £900 per tonne direct from the factory. 1 tonne = 1000kg.)*

4 *Would we save the amount of money estimated in question 3 if we recycled aluminium milk bottle tops and foil? Explain your answer.*

5 *What is meant by a 'non-renewable resource'?*

6 *Why is it important to recycle non-renewable resources like aluminium?*

7 *About 35 per cent of the aluminium used in Britain gets recycled. What difficulties are there in trying to recycle more?*

8 *Which forms of aluminium would be easiest to recycle? (Remember aluminium is used to make aircraft, parts of cars and lorries, caravans, saucepans and many other things as well as household foil.)*

9 *Practically all the gold we use gets recycled. Why is so much more gold recycled than aluminium?*

10 *List some other common household materials which can be recycled.*

Further questions and activities

- *The price of aluminium*

Find the mass and cost of a roll of aluminium foil. Calculate the cost per tonne of aluminium in the form of foil. Why does it cost so much more than aluminium direct from the factory (which costs £900 per tonne)?

- *The cost of electricity in aluminium manufacture* (This question is harder!)

(a) Calculate the number of moles of aluminium in 1 tonne (1 tonne = 1000 kg) of the metal. (Al = 27).

(b) When aluminium ore is electrolyzed, each aluminium ion is neutralized by three electrons:

$$Al^{3+} + 3e^{-} \longrightarrow Al$$

How many moles of electrons are needed for each mole of aluminium produced?

(c) How many coulombs of electric charge are needed to make 1 mole of aluminium? (1 mole of electrons = 1 Faraday = 96 500 coulombs)

(d) How many coulombs are needed to make 1 tonne of aluminium?

(e) Suppose the electrolysis is carried out at a voltage of 6V. Use your answer to (d) to find how many joules must be supplied to make 1 tonne of aluminium. (1 volt = 1 joule per coulomb.)

(f) From your answer to (e), calculate the number of units of electricity needed to make 1 tonne of aluminium. (1 unit = 1 kilowatt-hour = 3 600 000 joules.)

(g) If aluminium producers pay 3p a unit for electricity, calculate the cost of the electricity needed to make 1 tonne of aluminium.

(h) Apart from electricity, what other costs are involved in the manufacture of aluminium?

SATIS 3

List of units in this book

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