science at work

Biotechnology

Image removed

Biotechnology

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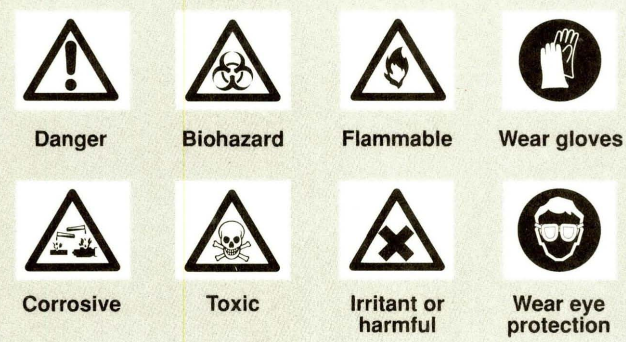
Contents

In this book you will find out about biotechnology and how it can affect your life. You will find out how microbes are used to do useful jobs in industrial processes. You will find out about enzymes and their use in the food industry. You will discover how useful living cells are and how they may help us in the future.



Good laboratory practice

These are the safety symbols used in this series. You should get to know them so that you can recognise hazards (dangers) that you might come across during your science lessons.

To avoid accidents you should:

- ☐ take special care when you see one of these symbols
- ☐ always read through **all** the instructions given before you start doing your experiments
- ☐ check with your teacher if you are not sure about any of the instructions
- ☐ always check with your teacher before beginning any investigation that you have designed yourself
- ☐ always wear eye protection when you see the eye protection symbol or when your teacher tells you
- ☐ always stand when you are handling liquids so that you can move out of the way quickly if you spill anything
- ☐ if you do spill any cultures of microbes on the bench tell your teacher. Be careful not to get it on your hands
- ☐ if you spill anything on your skin wash it off immediately with plenty of water. If you spill anything on your clothes tell your teacher
- ☐ if you get anything in your eyes flush it out with plenty of water and tell your teacher immediately.

1 Introduction

Biotechnology

Biotechnology uses living **cells**. Cells can make things that we want. Many of the methods used in biotechnology today were first used thousands of years ago.

Some people think that biotechnology is a new science. This is because there have been so many recent developments. Newspapers and television programmes often describe the results of research which may affect our lives.

Modern biotechnology has links with other branches of science like biology, microbiology, chemistry, biochemistry, genetics, chemical and genetic engineering, computer science and environmental science.

Q1 What is biotechnology?

Q2 What are some of the products of the oldest biotechnology processes?

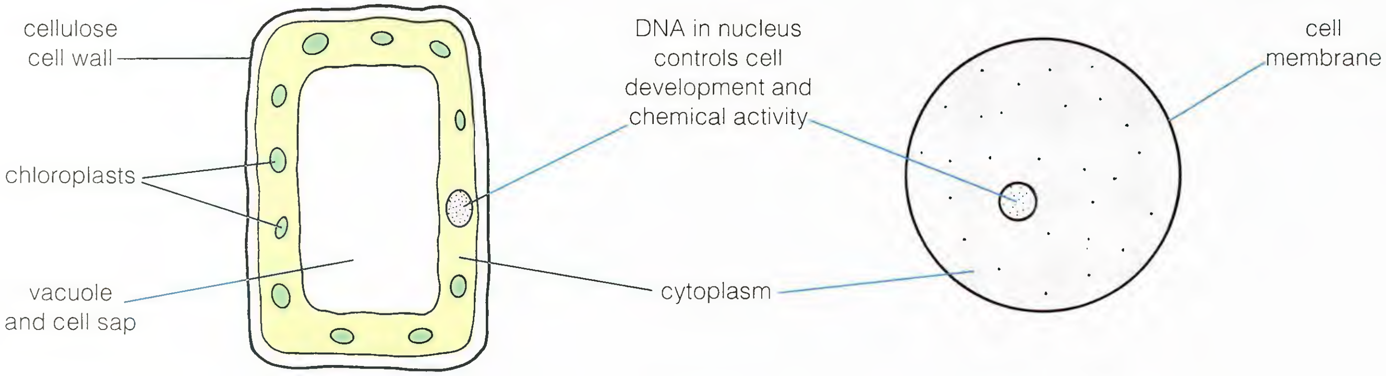
Q3 Modern biotechnology can be divided into several main areas of study. What are these areas?

Q4 What might make people think that biotechnology is a new science?

Extension exercise 1 can be used now.

Cells

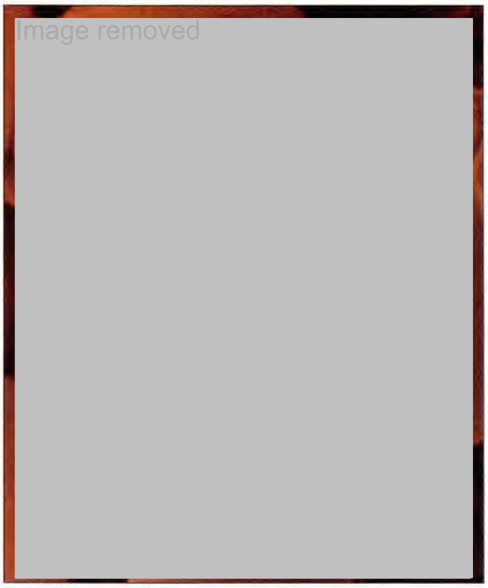
All plants and animals are made of **cells**. Individual cells can only be seen with a **microscope**. Single cells from plants and animals are used in biotechnology.



Single plant cell magnification ×300

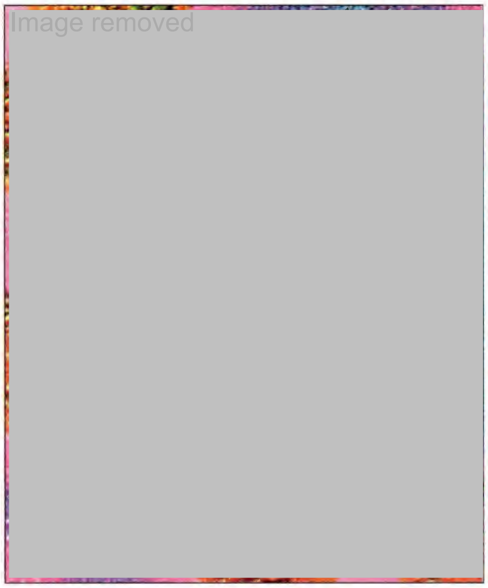
Single animal cell magnification ×300

Some small organisms consist of only one cell. **Microbes** are perhaps the most important group of organisms used in biotechnology. Microbes include **fungi** (moulds and yeasts), **bacteria** and **viruses**. Microbes are very small. A powerful **electron microscope** is needed to see them.



fungi × 6 000

bacteria × 13 500



viruses × 20 600

Q1 Which are the largest cells?

Q2 What magnification is needed to see the largest cells?

Q3 Which are the smallest microbes?

Q4 What magnification is needed to see the smallest microbes?

Q5 How are plant cells different from animal cells?

Q6 What does DNA do?

2 Enzymes

What are enzymes?

Enzymes control chemical reactions. They can build or break down substances. In this experiment, you are going to find out how heat affects the work of the enzyme amylase.

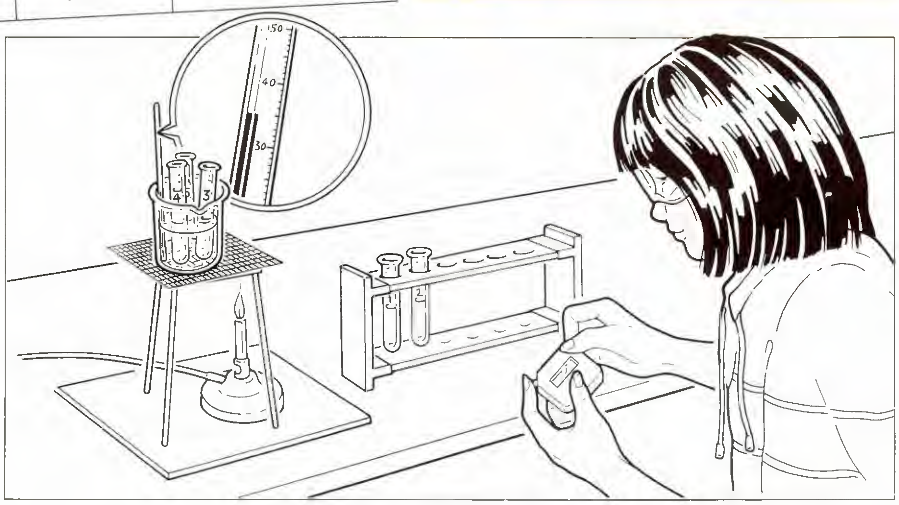
Q1 Copy this table.

Tube	Contents	Temperature	Colour with iodine solution after 20 minutes
①	10 cm^3 water	room	
②	10 cm^3 starch solution	room	
③	10 cm^3 starch solution	35°C	
④	10 cm^3 starch solution + 5 cm^3 amylase	35°C	
⑤	10 cm^3 starch solution + 5 cm^3 boiled amylase	35°C	

Apparatus

- ☐ starch solution ☐ water
- ☐ amylase solution
- ☐ boiled amylase solution
- ☐ 5 test tubes ☐ heatproof mat
- ☐ dropper pipette
- ☐ iodine solution ☐ stop clock
- ☐ 250 cm^3 beaker
- ☐ marker pen ☐ Bunsen burner
- ☐ tripod ☐ gauze
- ☐ test tube rack
- ☐ 10 cm^3 measuring cylinder
- ☐ 0–100°C thermometer
- ☐ eye protection

Wear eye protection.



A Label the test tubes 1–5. Add 10 cm^3 water to tube 1. Add 10 cm^3 starch solution to tubes 2–5. ▲

B Half fill the beaker with water. Heat it until there is a steady temperature of 35°C.

C Add 5 cm^3 of amylase to tube 4. Add 5 cm^3 of boiled amylase to tube 5. Shake tubes 4 and 5 gently to mix the contents. Place tubes 3, 4 and 5 in the prepared beaker for 20 minutes. ▲

D Add 4 drops of iodine solution to test tubes 1–5. Record your results in your table. ◀

Q2 What colour is iodine solution when starch is present?

Q3 What colour is iodine solution when starch is absent?

Q4 Is starch solution destroyed, or changed, by heating it at 35–40°C? Explain your answer.

Q5 What does amylase do to starch? Explain your answer.

Q6 How is amylase affected by boiling?

Extension exercise 2 can be used now.

Living cells and enzymes

Hydrogen peroxide is a poison that can form in living cells. An enzyme called catalase can change it to harmless water and oxygen. In this experiment, you are going to find out how living things react with hydrogen peroxide.

1 Look carefully to see if any bubbles are produced.
2 If there are lots of bubbles test them with a glowing spill; it will relight if oxygen is present.
3 Measure the height of any froth or foam produced.

Q1 Copy this table.

Tube	Contents	Amount of Bubbles	Test with glowing spill	Height of froth (mm)
①	apple			
②	chopped apple			

Apparatus

- ☐ apple ☐ potato ☐ meat
- ☐ liver ☐ hydrogen peroxide
- ☐ knife ☐ cutting tile
- ☐ 0–10 cm^3 measuring cylinder
- ☐ Bunsen burner ☐ heatproof mat
- ☐ 2 wooden spills ☐ mm ruler
- ☐ 8 test tubes ☐ test tube rack
- ☐ eye protection

Wear eye protection.

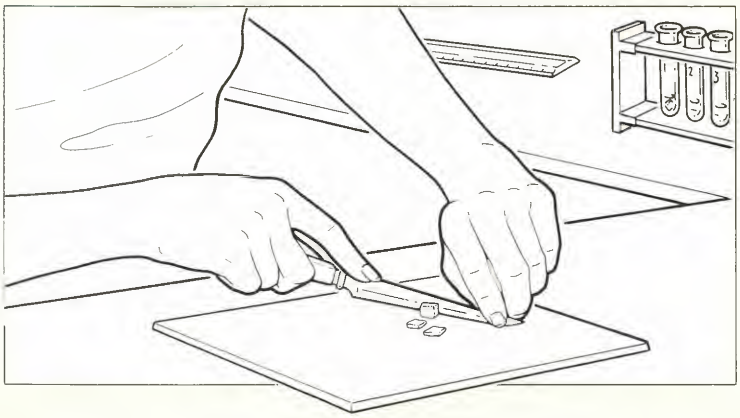
Handle the hydrogen peroxide with care.

A Label the test tubes 1–8. Add 2 cm^3 hydrogen peroxide to each tube. ▲

B Add a cube of apple to tube 1. Record your results in the table. ▲

C Chop up another cube of apple. Add the small pieces to tube 2. Records your results in the table. ▼

D Repeat **B** and **C** for potato, meat, and liver. Record your results after each test.



Q2 Which was best at changing hydrogen peroxide?

Q3 Which cells, plant or animal, worked the fastest?

Q4 Why do living cells break down hydrogen peroxide?

Q5 How do the cells break down hydrogen peroxide?

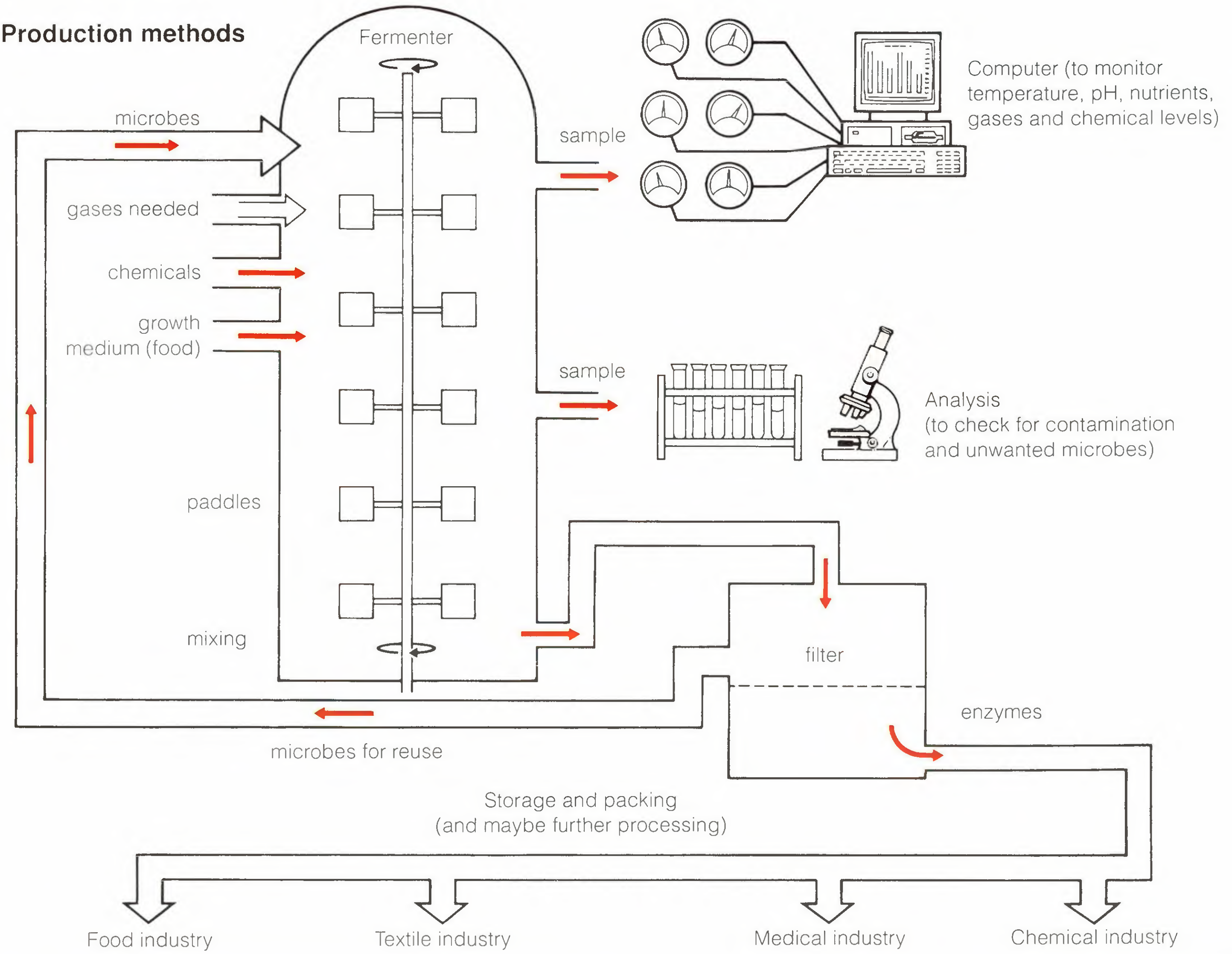
Q6 How did chopping up the apple, potato and so on, alter the speed of the reaction and why?

Enzymes and industry

All living cells make enzymes to control their chemical reactions.

Enzymes control the speed at which substances are built up or broken down. Enzymes are not changed by these reactions. They can be reused so only small amounts are needed. There are many industrial processes which use enzymes to do chemical work. **Biotechnologists** have found which microbes make the enzymes that are needed. They have found the best conditions for keeping these microbes. The enzymes that they make are collected easily.

Production methods



Q1 What do enzymes do?

Q2 What must biotechnologists know before they can collect enzymes?

Q3 Where are microbes kept when they are making enzymes?

Q4 What do microbes need to stay alive?

Q5 What is used to monitor the enzyme production process?

Q6 What is the filter used for?

Extension exercise 3 can be used now.

Biological washing powders

Biological washing powders contain enzymes. The makers claim they are good at removing stains. In this experiment you are going to find out if this is really true.

Q1 Copy this table.

Cloth number	Stain	Appearance at first	Appearance after washing
1	coffee		
2	grass		
3	blackcurrant juice		
4	biro ink		
5	grease		
6	chocolate		

Apparatus

☐ 6 labelled containers of white cloth stained with: coffee, grass, blackcurrant juice, biro ink, grease, chocolate ☐ gauze
☐ biological washing powder
☐ spatula ☐ measuring cylinder
☐ large beaker ☐ stirrer
☐ waterproof marker pen
☐ Bunsen burner ☐ tripod
☐ stop clock ☐ heatproof mat
☐ 0–100°C thermometer
☐ eye protection ☐ forceps

Wear eye protection.

Some people are allergic to biological washing powders.

A Number each piece of cloth. Describe the appearance of the stain in your table. ▲

B Add 10 spatulas of washing powder to the large beaker. Add 150 cm^3 water gradually, stirring until the powder is dissolved. Repeat these steps until the beaker is half full. Warm the water gently until it reaches 30°C. Turn the Bunsen out. ▲

C Add the pieces of cloth. Stir the contents of the beaker frequently. ▲

D After 15–20 minutes use forceps to remove each piece of cloth. Rinse each one in cold water. Let the cloth dry. Complete your results table. ▶

Q2 Which stains were removed best?

Q3 Which stains remained?

Q4 Why do you think that the powder could remove stains?

Q5 What did your experiment show about the claims made for stain removal?

Q6 What, if any, were the warnings given about using biological washing powder?

Q7 Was your method of testing the washing powder fair? Could you get better results? Explain your answer.

A whiter wash?

In this experiment, you are going to find out how biological washing powders compare with non-biological powders at different temperatures.

Q1 Copy this table.

Beaker	Temperature °C	Powder	Appearance of cloth at first	Appearance of cloth after washing
1	100 (very hot)	biological		
2	100 (very hot)	non-biological		
3	30 (warm)	biological		
4	30 (warm)	non-biological		

Apparatus

- ☐ 4 × 250 cm^3 beakers ☐ spatula
- ☐ marker pen ☐ eye protection
- ☐ measuring cylinder ☐ stirrer
- ☐ 4 pieces of stained white cloth
- ☐ Bunsen burner ☐ tripod
- ☐ forceps ☐ gauze
- ☐ 0–100°C thermometer
- ☐ biological washing powder
- ☐ 4 heatproof mats ☐ stop clock
- ☐ non-biological washing powder

Wear eye protection.

Some people are allergic to biological washing powders.

A Label the beakers 1, 2, 3 and 4. Add 150 cm^3 water to each beaker. Complete the first column of the table. ▲

B Boil the water in beaker 1. Add 10 spatulas of biological washing powder. Stir until it dissolves. Add a piece of cloth. Put the beaker on a mat and leave for 15–20 minutes. Stir it often. Remove the cloth using forceps. Rinse it in cold water and let it dry. Complete the first row of the table. ▲

C Repeat **B** for beaker 2 but this time using the non-biological washing powder. Record your results. ▲

D Repeat **B** for beakers 3 and 4 using water at 30°C. Take care to use the correct powder. Complete your table. ▲

Q2 Which powder gave the best results in cool water?

Q3 Which powder gave the best results in the very hot water?

Q4 Why are the results affected by temperature?

Q5 If both powders cost the same, which would be the cheapest powder to use at home? Explain your answer.

3 The food industry

Making yoghurt

People have made yoghurt for thousands of years. In hot countries it was a good way to preserve milk. Today you are going to make yoghurt.

Q1 Copy the table.

Beaker	Contents	Appearance of contents after 1–2 days
X	milk and boiled yoghurt	
Y	milk and unboiled yoghurt	

Apparatus

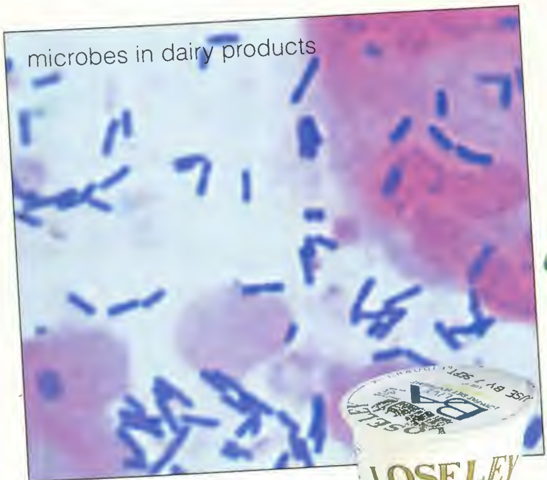
- ☐ teaspoon ☐ eye protection
- ☐ natural live yoghurt ☐ stirrer
- ☐ 2 × 250 cm^3 beakers ☐ gauze
- ☐ marker pen ☐ heatproof mat
- ☐ clingfilm ☐ UHT milk
- ☐ Bunsen burner ☐ tripod

Wear eye protection.

Do not taste the yoghurt you make.

A Label 2 beakers X and Y. Put 3 teaspoons of yoghurt into each one. Gently heat beaker X. Stir until it boils. Leave it to cool. ▲

B Add milk to half fill beaker X and stir it. Repeat this step for beaker Y. Cover each beaker and keep them warm for 24 hours. Then keep them in a fridge for 1–2 days. Observe and record the results. ▲



microbes in dairy products

Q2 Why was yoghurt made?

Q3 What could have been destroyed by boiling?

Q4 Why do you think that the beakers had to be covered?

Q5 Which beaker produced a substance most like yoghurt?

Q6 What do you think changes milk to yoghurt?

Making cheese

In this experiment you are going to find out how to turn milk into cheese.

Q1 Copy this table.

Beaker	Contents	Appearance				
		at start	after 15 minutes	after 1–2 days	solid left in filter paper	liquid passed through filter paper
1	milk and lemon juice					
2	milk and microbes					

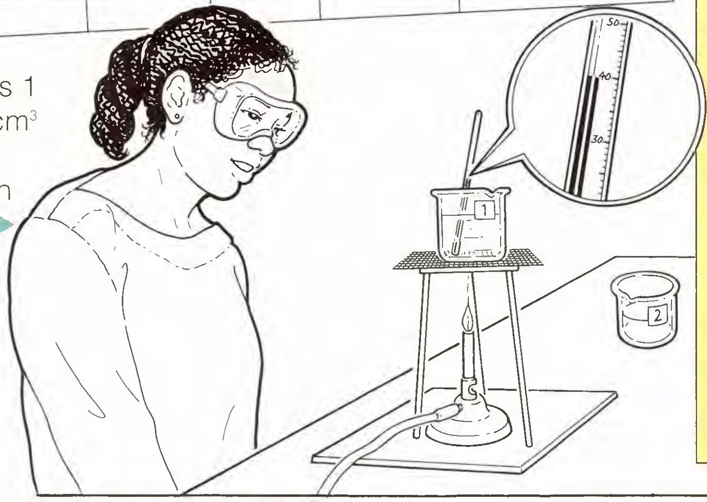
Apparatus

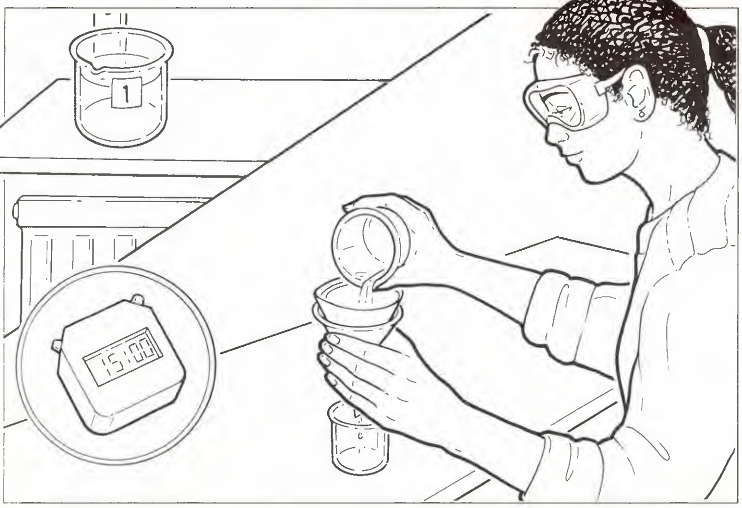
- ☐ 2 × 250 cm³ beakers
- ☐ 0–20 cm³ measuring cylinder
- ☐ 0–100°C thermometer
- ☐ Bunsen burner ☐ tripod
- ☐ gauze ☐ heatproof mat
- ☐ 2 filter funnels ☐ filter paper
- ☐ clingfilm ☐ lemon juice
- ☐ microbe culture ☐ marker pen
- ☐ pasteurised milk
- ☐ 2 small beakers
- ☐ eye protection

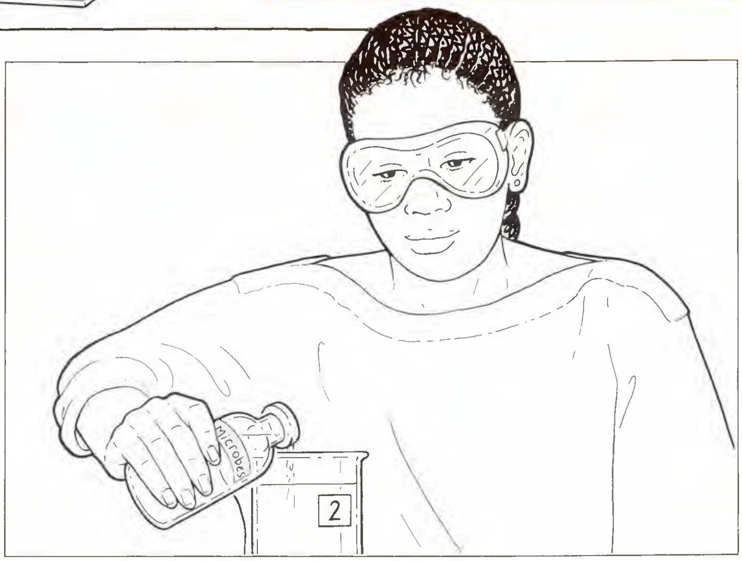
Wear eye protection.

Do not taste the cheese you make.

A Label the beakers 1 and 2. Add 150 cm³ of milk to each beaker. Warm the milk in both beakers to 40°C. ▶







B Add 15 cm³ lemon juice to beaker 1 and stir. Make a note of the appearance in your table. Keep this beaker in a warm place for 15 minutes. Fill in the next part of your table. Filter the contents of the beaker. You may have to leave this until the next lesson before you can complete the table. ▲

C Add the sample of microbes to beaker 2 and stir. Wash your hands! Make a note of the appearance in your table. Cover this beaker and keep it in a warm place for 1–2 days. Filter the contents of beaker 2 as in **B**. Complete the last sections of your table. ▲

Q2 What happened to the milk in beaker 1 after 15 minutes?

Q3 What sort of chemical is lemon juice?

Q4 What did the microbes do to the milk after 1–2 days?

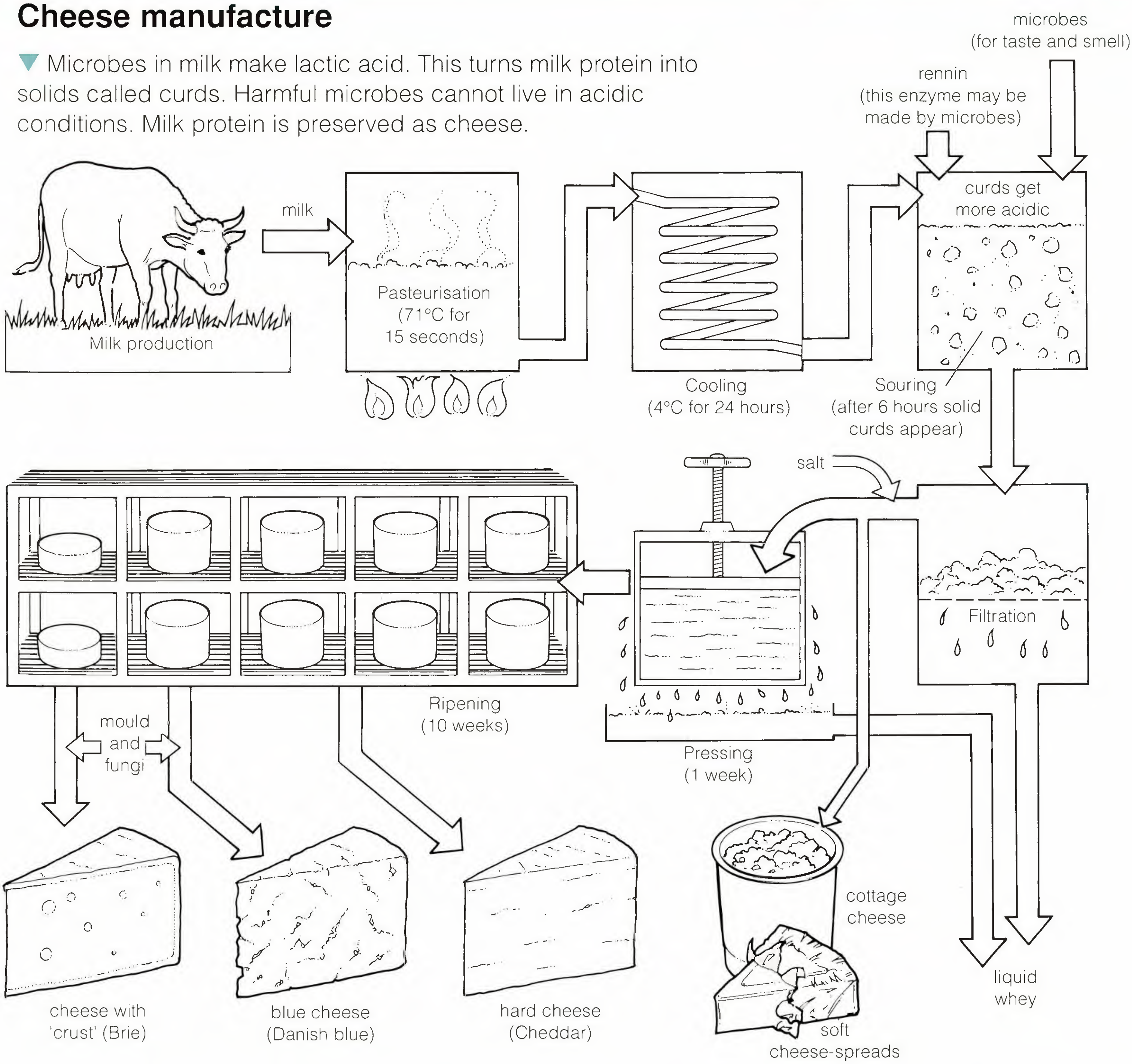
Q5 What could the microbes have made to curdle the milk?

Q6 What produced a solid which looked and smelt most like cheese?

Q7 How could the solid be changed to look like a hard cheese?

Cheese manufacture

▼ Microbes in milk make lactic acid. This turns milk protein into solids called curds. Harmful microbes cannot live in acidic conditions. Milk protein is preserved as cheese.



Q1 Why are microbes added to milk?

Q2 Why is rennin added?

Q3 The curds get more acidic. Why is this useful?

Q4 How is the curd separated from the liquid?

Q5 What sort of cheese is produced by just adding salt to the curd?

Q6 How is curd made into hard cheese?

Q7 How are blue cheeses made?

Q8 Different treatments produce many different tasting cheeses. List as many different cheeses as you can.

Bread

Bread is made from wheat flour and **yeast**. Wheat has enzymes which change starch to sugar. Yeast is a fungus which feeds on sugar. Its enzymes break down the sugar in the flour. Carbon dioxide is made. This gas makes the dough rise. The dough is baked to make bread. You are going to find out how well yeast works.

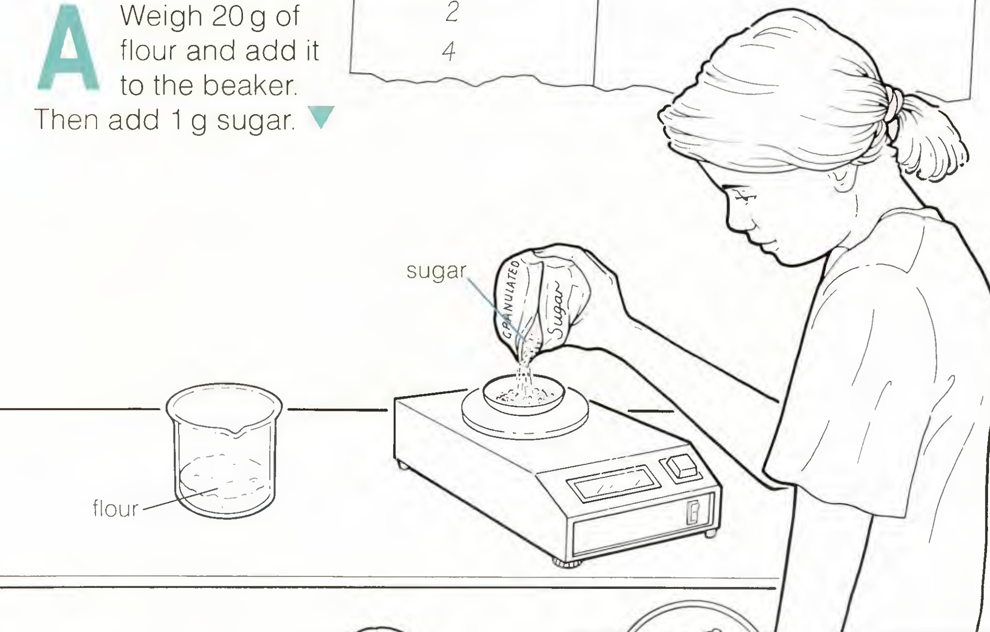
Apparatus

- ☐ plain flour ☐ sugar
- ☐ top pan balance
- ☐ 250 cm^3 beaker
- ☐ 25 cm^3 measuring cylinder
- ☐ yeast solution ☐ stirrer
- ☐ 250 cm^3 measuring cylinder
- ☐ stop clock ☐ slice of bread

Q1 Copy this table.

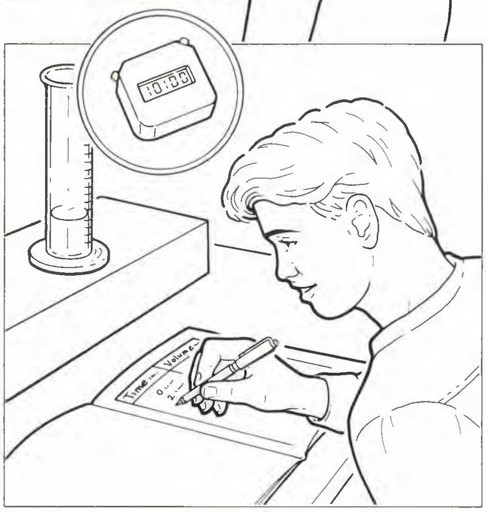
Time (mins)	Volume (cm^3)
0 (start)	
2	
4	

A Weigh 20 g of flour and add it to the beaker. Then add 1 g sugar.

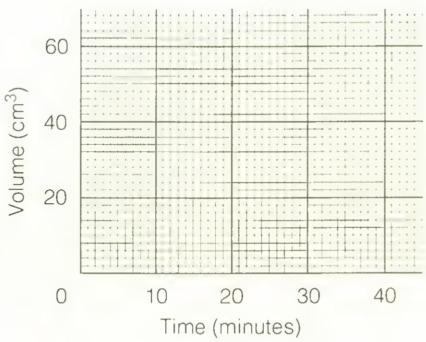


B Measure 25 cm^3 yeast solution. Add this to the contents of the beaker. Stir until it is smooth.

C Carefully pour the contents of the beaker into the 250 cm^3 measuring cylinder. *Do not* let the contents touch the sides!



D Record the volume of the paste every 2 minutes for 30 minutes.



E Plot a line graph of your results.

Q2 What made the dough rise?

Q3 Why was sugar added?

Q4 What does the yeast make to break down sugar?

Q5 What can you see in a slice of bread that shows that yeast produced a gas?

Fermentation

Yeast is often found on the surface of sweet fruits. In **fermentation** enzymes produced by yeast change sugar into carbon dioxide and alcohol. Carbon dioxide turns lime water cloudy. Alcohol has a special smell.

Q1 Copy this table.

	At start	After 1–2 weeks
colour of lime water		
appearance of juice		
smell of juice		

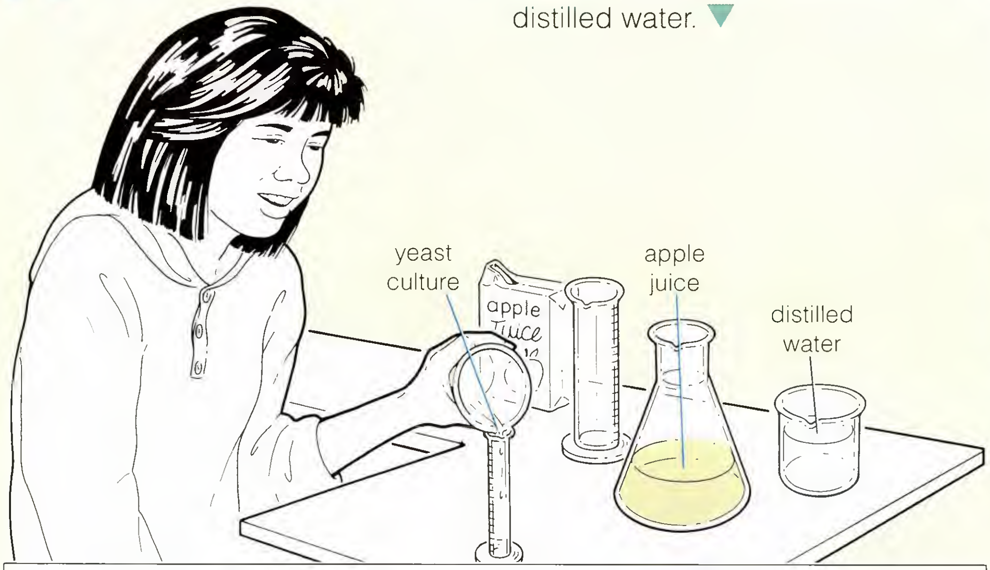
Apparatus

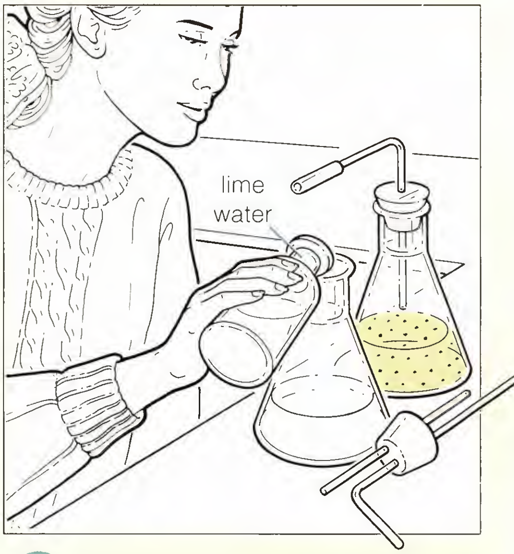
- ☐ apple juice ☐ yeast culture
- ☐ distilled water ☐ lime water
- ☐ 2 × 250 cm^3 flasks
- ☐ 10 cm^3 measuring cylinder
- ☐ 100 cm^3 measuring cylinder
- ☐ 2 bungs with glass tubing and rubber connectors
- ☐ sterilising solution

Do not taste anything in the lab.

A Rinse all the apparatus in sterilising solution to kill all the microbes.

B Measure 100 cm^3 apple juice into a flask. Add 4 cm^3 yeast culture. Then add 6 cm^3 distilled water. ▼





C Add enough lime water to the second flask so that the end of the glass tube will be in the liquid. ▲

D Add the bungs and glass tubing as shown. Complete the second column of your table. Keep the flasks warm for 1–2 weeks. Complete your table. ▲

Q2 What signs are there that changes are occurring in the first flask?

Q3 How do you know that the gas produced is carbon dioxide?

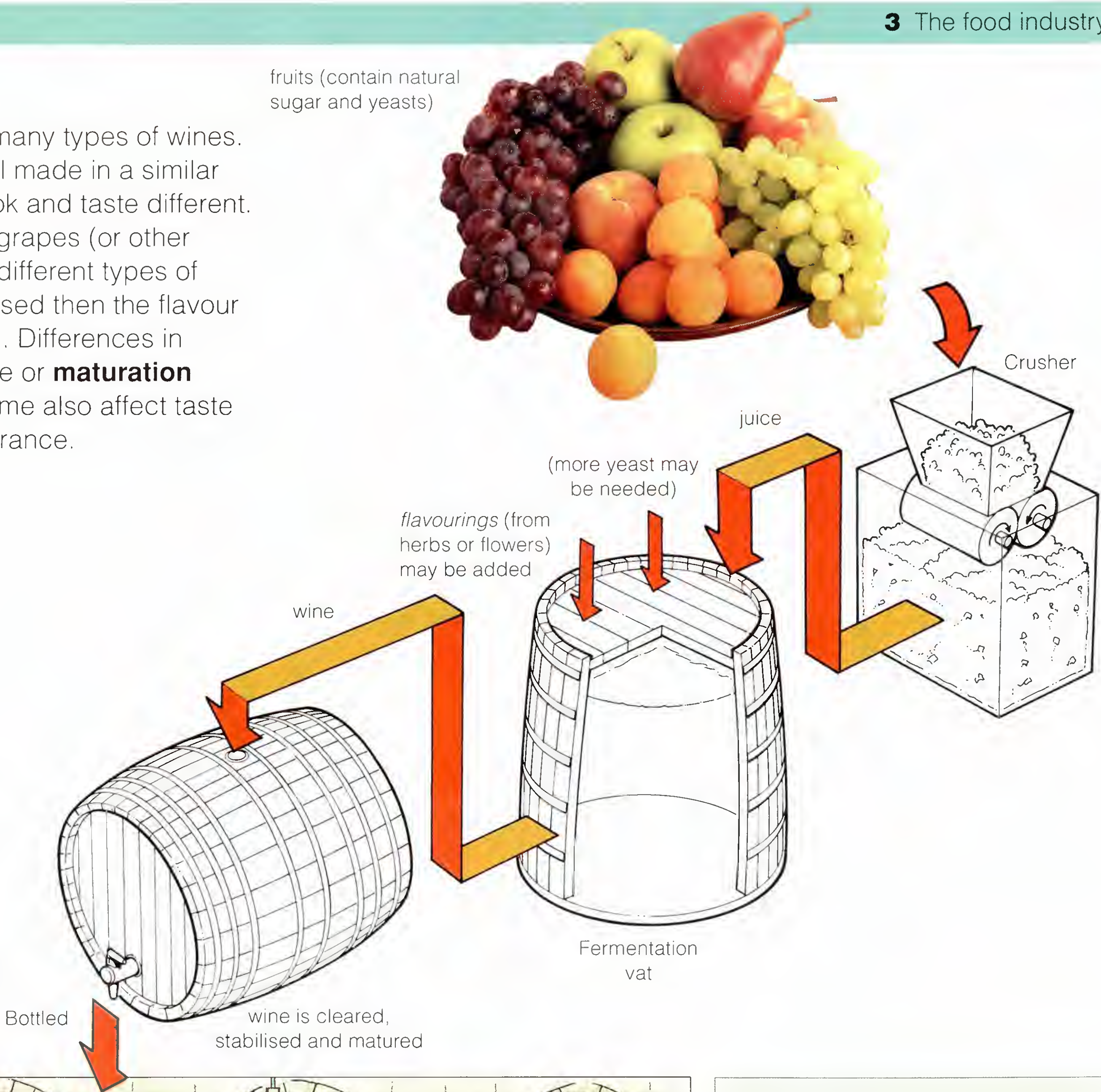
Q4 What do the contents of the flask smell like at the end of the experiment?

Q5 Apart from your age, why do you think that you are not allowed to taste what is in the flask?

Q6 Why do you think the yeast stops making carbon dioxide?

Wine

There are many types of wines. They are all made in a similar way but look and taste different. If different grapes (or other fruits) and different types of yeast are used then the flavour is changed. Differences in temperature or **maturation** (storage) time also affect taste and appearance.



Q1 Why is the fruit crushed?

Q2 Why isn't it always necessary to add yeast?

Q3 What happens if different fruits or yeast are used?

Q4 What is happening during fermentation?

Q5 What is done after fermentation before the wine is bottled?

Extension exercise 4 can be used now.

Apparatus

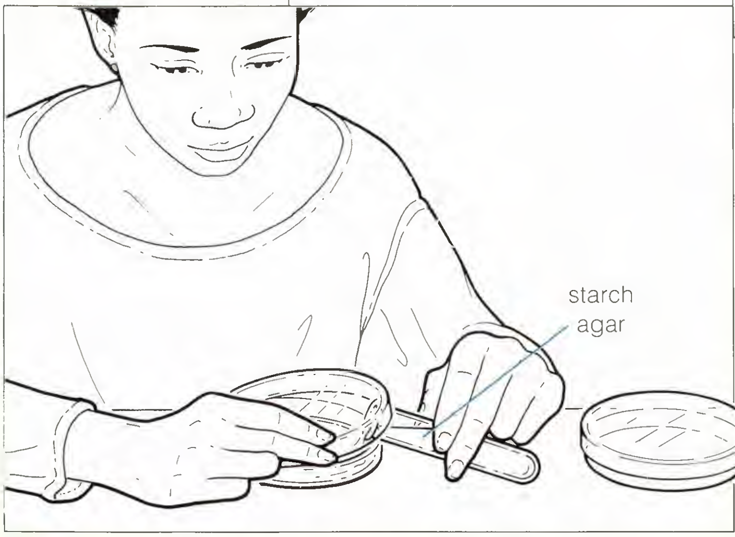
- ☐ 2 sterile Petri dishes ☐ scalpel
- ☐ 2 tubes of melted starch agar
- ☐ marker pen ☐ 2 maize grains
- ☐ 2 boiled maize grains
- ☐ forceps ☐ dilute iodine solution
- ☐ cutting tile ☐ eye protection

Germinating maize

Germinating grains are used to make beer. Grains like maize (sweetcorn) contain starch. They need energy to **germinate** and grow. Sugar can provide energy. You are going to find out what happens when maize germinates.

Q1 Copy this table.

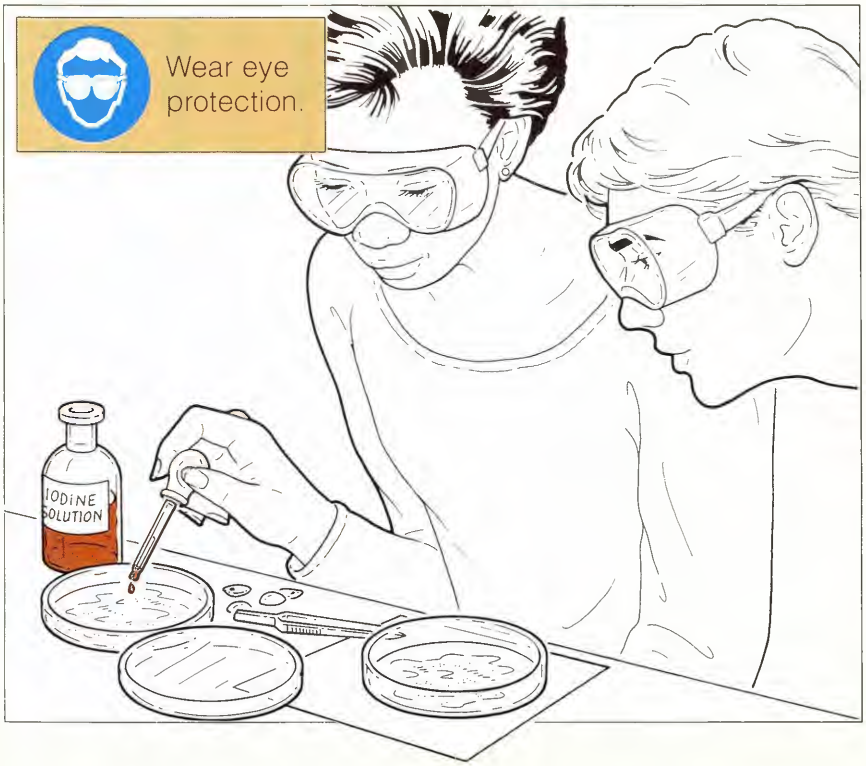
Final appearance	
① unboiled grain and starch agar	② boiled grain and starch agar



A Label the bottom of each dish with your name, date and dish number. Quickly pour the starch agar into each dish. Quickly replace their lids. Leave the dishes until the agar has set. ▲

B Cut each unboiled grain in half as shown. Using forceps place them, cut side down, on the agar of dish 1. Quickly replace the lid. Repeat using the boiled grains for dish 2. ▲

Wear eye protection.



C Leave the dishes in a warm place for 1–7 days. Remove the dish lids. Remove the grains with forceps. Add dilute iodine solution to cover the agar surface of each dish. After 1–2 minutes pour the liquid off. Look at the dishes over a white background. Record your results in the table. ◀

Q2 What is stored in grains?

Q3 What do the grains need for growth and germination?

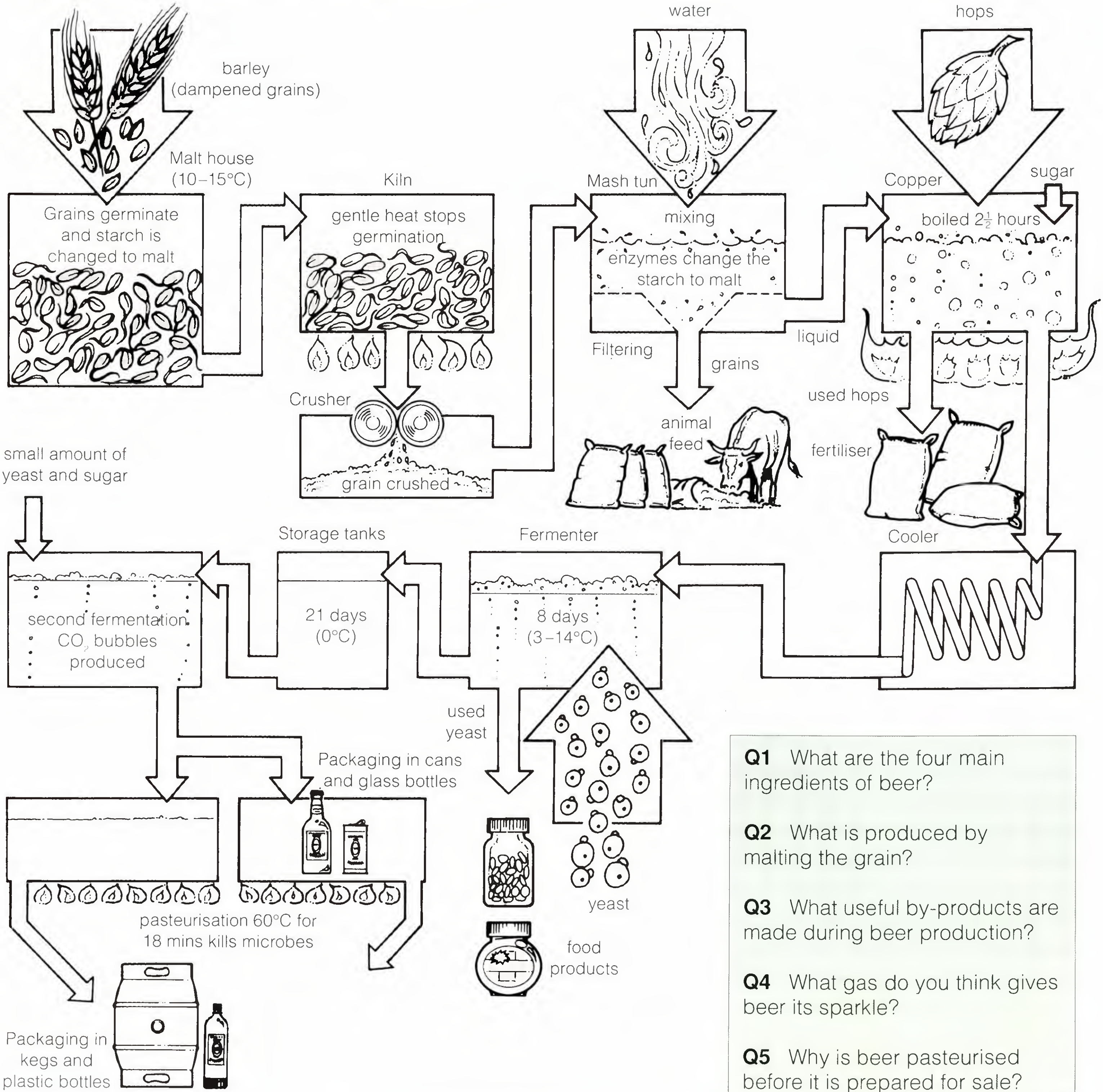
Q4 Iodine solution turns blue-black with starch. What do your results show in dish 1?

Q5 What is the effect of boiling the grains?

Q6 How could the maize grains produce these results?

Beer

▼ Barley grains contain stored starch. Before the barley can germinate and grow, its enzymes have to change the starch into sugar. This is the first stage in beer production.



Q1 What are the four main ingredients of beer?

Q2 What is produced by malting the grain?

Q3 What useful by-products are made during beer production?

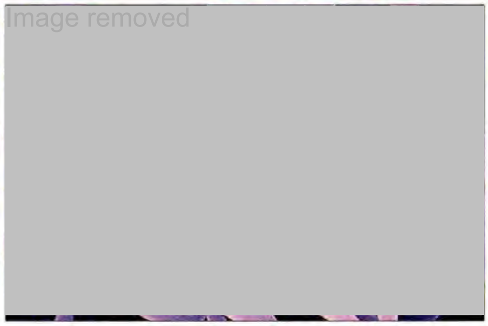
Q4 What gas do you think gives beer its sparkle?

Q5 Why is beer pasteurised before it is prepared for sale?

Extension exercise 5 can be used now.

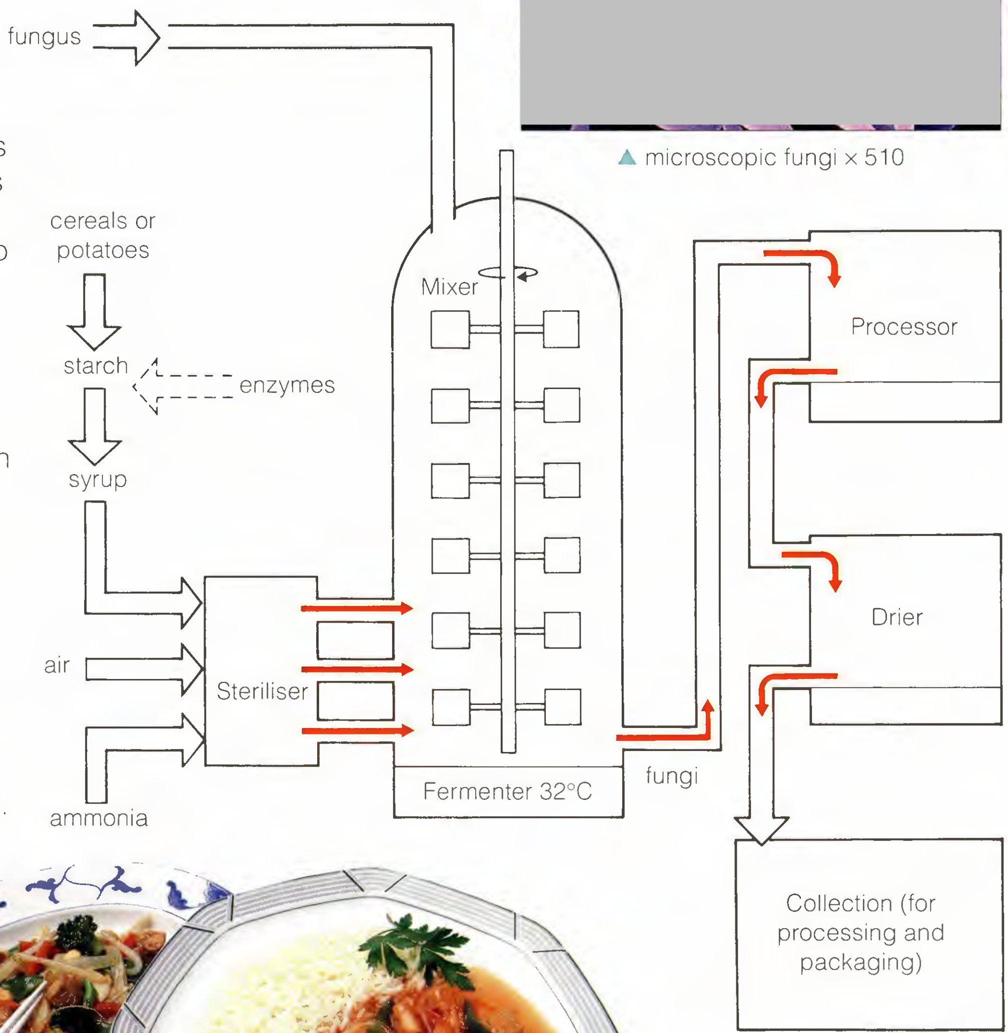
Mycoprotein

The world population has grown quickly. Producing enough cheap food for everyone is a problem. New foods are needed.



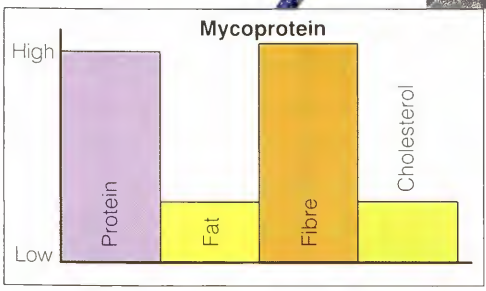
▲ microscopic fungi × 510

There are thousands of different types of **fungi**, including edible mushrooms and poisonous toadstools. Little was known about the microscopic fungi so they were investigated. Tests were done to see if they could be eaten. For safety, testing was done for 10 years. Scientists found an easy way of growing these fungi. Cheap carbohydrates were turned into a high protein food called **mycoprotein**, shown in the photograph. This was first made in the 1960s. Microscopic fungi do not need much space and grow quickly. They can double their weight every 5 hours. Producing the same weight of traditional plant or animal food needs a lot of space and takes a very long time. The diagram shows how mycoprotein is produced.



▶ Mycoprotein can be used in many different ways.

▼ Mycoprotein is nutritious.



Q1 Why were the fungi tested?

Q2 Why was the testing done for so long?

Q3 Why do you think the non-living things were sterilised?

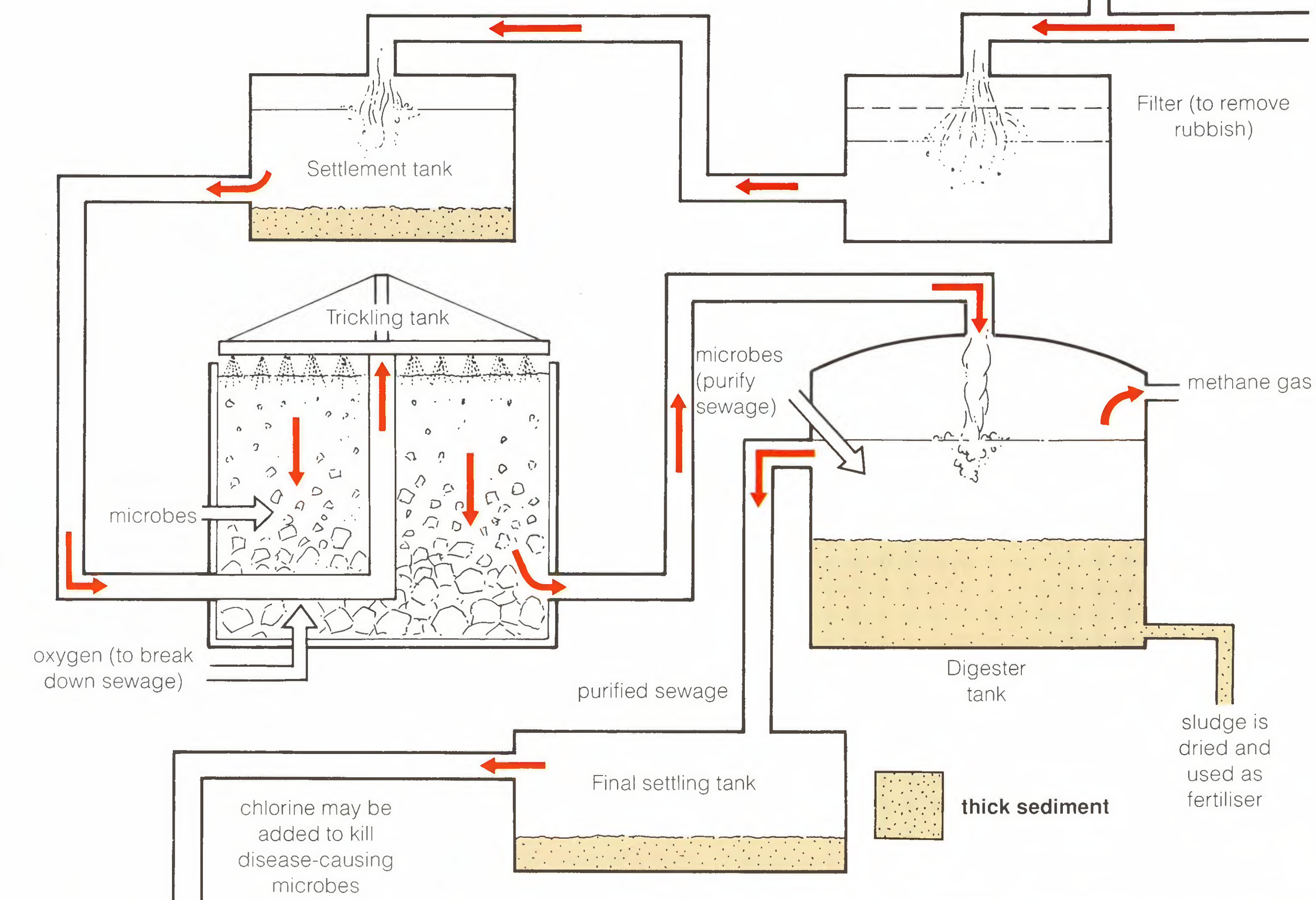
Q4 Why is it better to produce mycoprotein than plant or animal food?

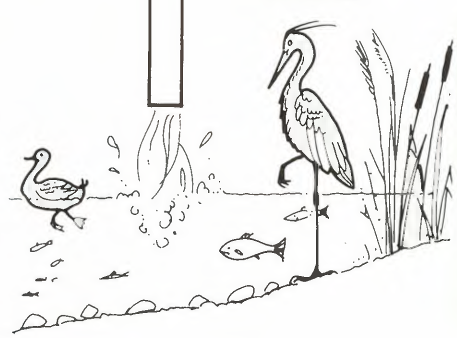
Q5 Why is mycoprotein a healthy food?

4 Our water supply

Sewage disposal

Dirty water is collected from our homes and factories in underground pipes called **sewers**. In Britain 400 litres of **sewage** is produced per person each day. This is because so much water is used in factories and homes. Diseases like cholera, polio, gastric 'flu and food poisoning can be passed on by infected sewage. Poisonous wastes in the water from factories could damage the environment. It is important that sewage is made safe to protect our health and our environment.





Q1 What is sewage?

Q2 Why shouldn't untreated sewage be passed into the sea and the rivers?

Q3 Why are microbes useful in sewage treatment?

Q4 What can sludge be used for?

Q5 What sort of microbes would be killed by the addition of chlorine?

Q6 How do you think that the EC (European Community) checks how clean and safe beaches are?

Safe water

We each use 120 litres of water a day. Water can be **contaminated** by disease-causing microbes and **pollution**. It is made safe to drink at the water works. You are going to find out how **filtration** changes water.

Q1 Copy the table.

	Appearance
soil water at start	
filtered soil water at start	
dish 1 (soil water)	
dish 2 (filtered soil water)	

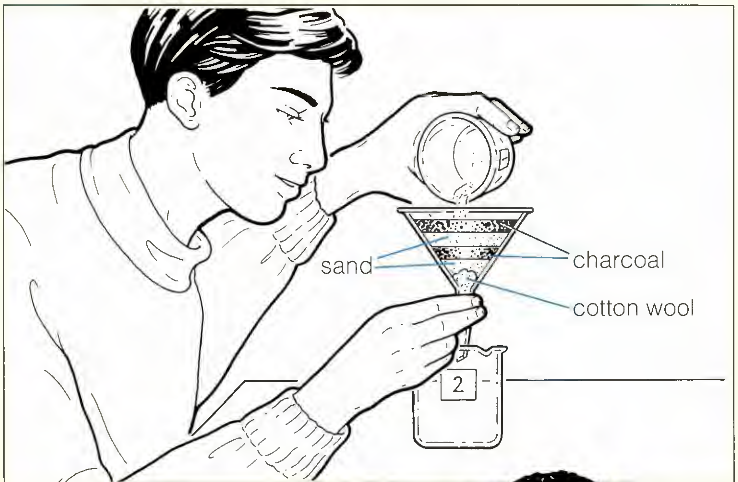
Apparatus

- ☐ charcoal ☐ sand
- ☐ cotton wool ☐ soil ☐ water
- ☐ dropper pipette ☐ glass rod
- ☐ 2 Petri dishes of agar
- ☐ filter funnel ☐ marker pen
- ☐ 2 small beakers ☐ sticky tape

Do not drink any of the water in this experiment.

A Label the beakers 1 and 2. Add some water to beaker 1. Add some soil and stir. Complete the first row of the table. ▼

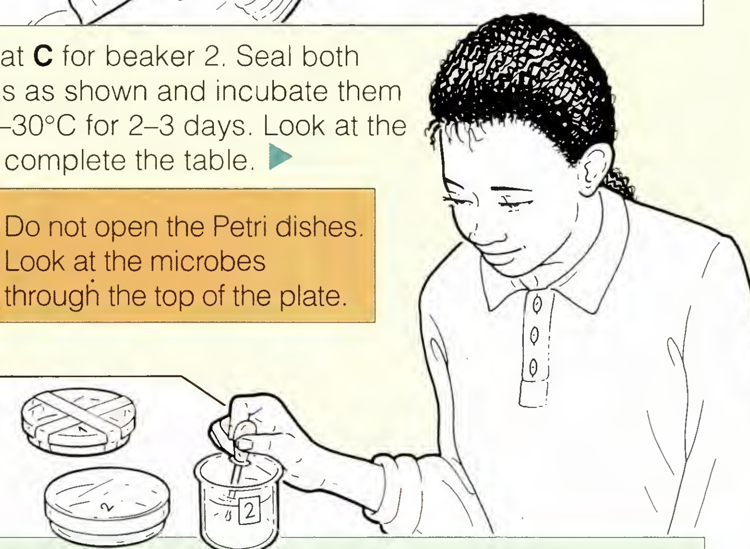
B Prepare the filter funnel as shown. Add most of the water from beaker 1. Collect the filtered water in beaker 2. Complete the top part of the table. ▼



C Label the bottom of each Petri dish with your name, the date and dish number. Use a pipette to take a small sample from beaker 1. Lift the lid of dish 1 as little as possible and add the sample to the agar. Quickly close the lid. ▼

D Repeat **C** for beaker 2. Seal both dishes as shown and incubate them at 25–30°C for 2–3 days. Look at the dishes and complete the table. ▶

Do not open the Petri dishes. Look at the microbes through the top of the plate.



Q2 How did filtration change the water?

Q3 Which dish contained the most microbes?

Q4 Does filtering remove any microbes?

Q5 Would the water be safe to drink after filtering?

Microbes and chlorine

Chlorine is found in bleach, household cleaners, tap water and the water at the swimming baths. In this experiment you are going to find what chlorine does to *E.coli* microbes.

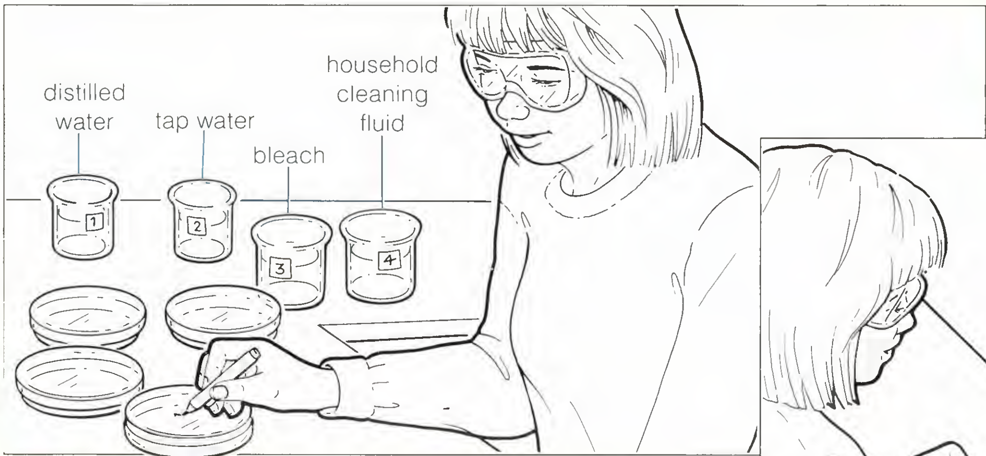
Q1 Copy the table.

Dish	Contents	Appearance of dish after 2–3 days
1	distilled water	
2	tap water	
3	bleach	
4	household cleaner	

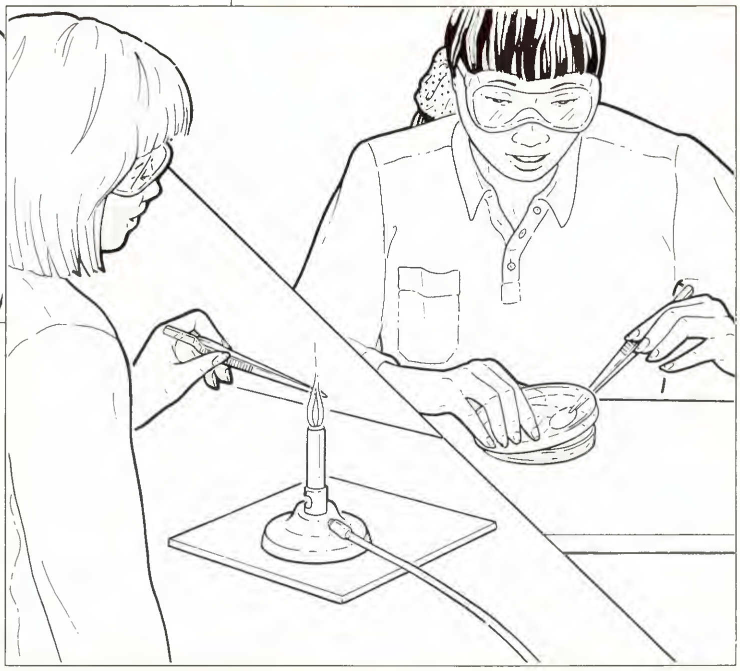
Apparatus

- ☐ 4 Petri dishes of agar and *E.coli* microbes
- ☐ 4 paper discs
- ☐ sticky tape ☐ forceps
- ☐ Bunsen burner ☐ marker pen
- ☐ heatproof mat ☐ labels
- ☐ eye protection ☐ bleach
- ☐ 4 small beakers
- ☐ distilled water ☐ tap water
- ☐ household cleaning fluid

Wear eye protection.



A Label the bottom of each Petri dish with your name, the date and dish number. Label the beakers 1, 2, 3 and 4. ▲



B Flame the forceps. Dip a disc into beaker 1. Gently shake off any drops. Lift the lid of dish 1 as little as possible. Place the disc as shown. Quickly close the lid. Repeat these steps for 2, 3 and 4. Seal all the dishes. ▲

C Incubate the dishes at 25–30°C for 2–3 days. Look at your results and complete the table. ▲

Do not open the Petri dishes. Look at the microbes through the top of the plate.

Q2 Why did you flame the forceps?

Q3 Why did you use distilled water in dish 1?

Q4 If there are no living microbes the agar stays clear. Which liquid was best at killing the microbes?

Q5 Why is a small amount of chlorine added to our water supply?

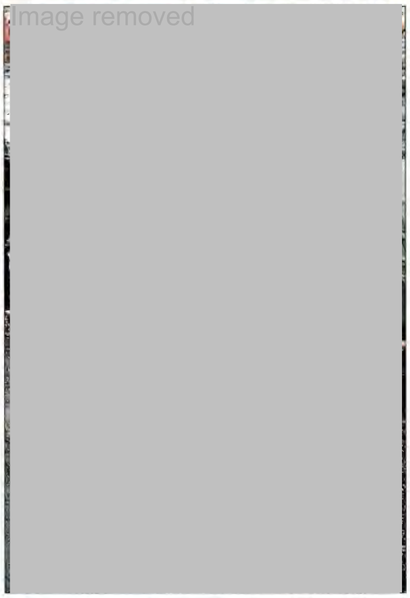
Q6 Why is even more chlorine added to the water at the swimming baths?

Wastes and microbes

Industrial wastes can cause pollution.
Microbes can make some pollutants harmless.

Oil and petrol

▶ Detergents can disperse oil spills but are harmful to living things. Microbes do the same work more safely.



Paper mills

▲ Mills make sulphites which can pollute rivers. These poisonous wastes use up oxygen so living things die. Fungi make the wastes safe and let bacteria live. These microbes can change some wastes into animal food and produce useful methane gas.

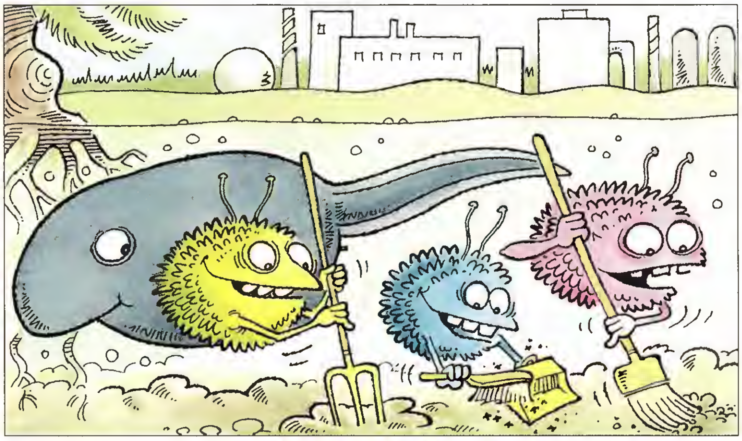
Acid rain

▼ Releasing sulphur dioxide and nitrogenous gases into the air causes acid rain. Microbes can make these gases safe. They cost less to use than chemical controls.

Chemical pollution

▼ Enzymes, from microbes, can make some chemicals like detergents, herbicides and pesticides safe. Microbes can remove poisonous metals, like lead and mercury, from wastes leaving a safe liquid.

In the future other pollutants could be made safe. **Genetic engineering** could produce microbes that make the exact enzymes needed.



Q1 Why are oil spills a problem?

Q2 What can microbes make from paper mill wastes?

Q3 What is the advantage of using microbes to prevent acid rain?

Q4 How do microbes help to prevent chemical pollution?

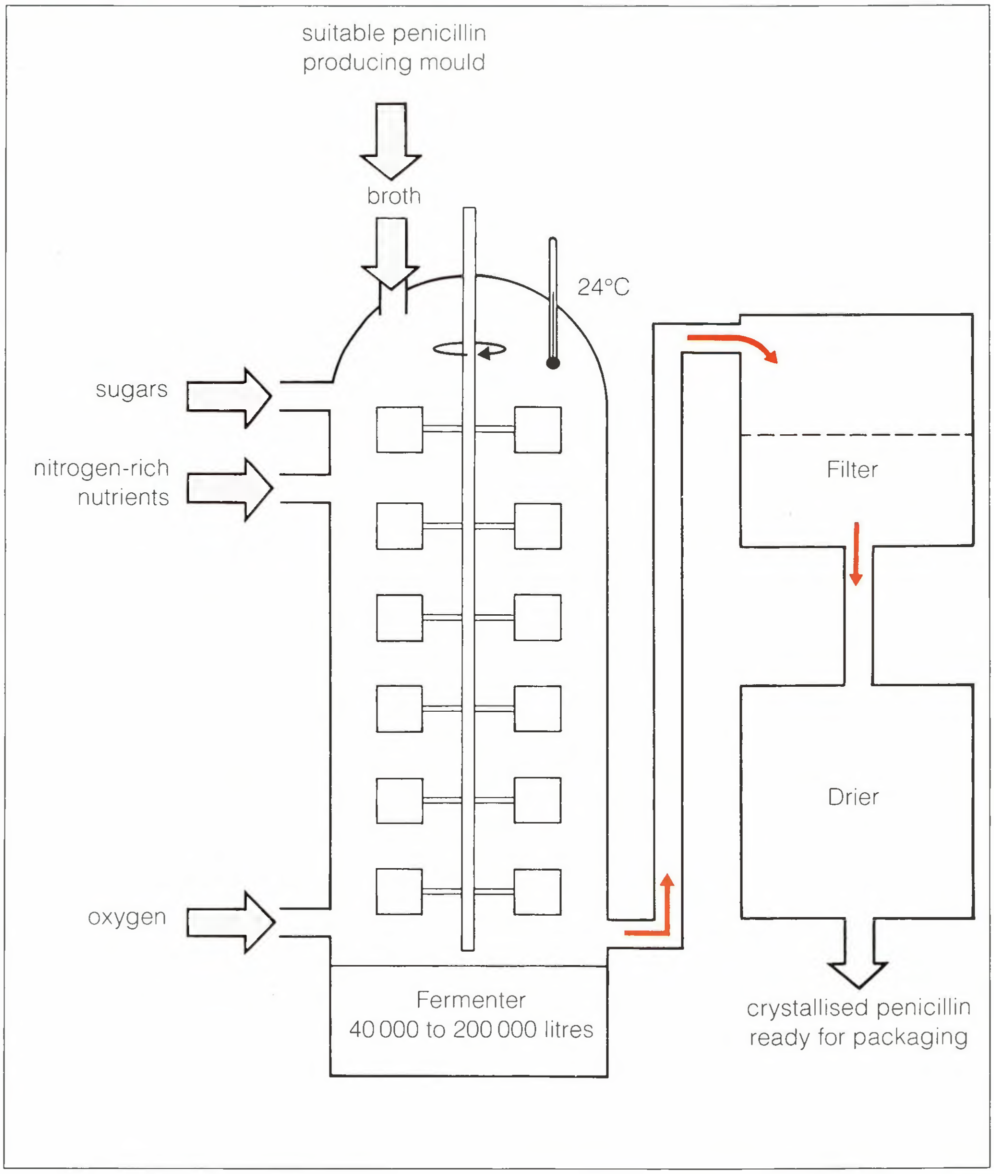
Q5 How could microbes be used in the future?

5 Medical applications

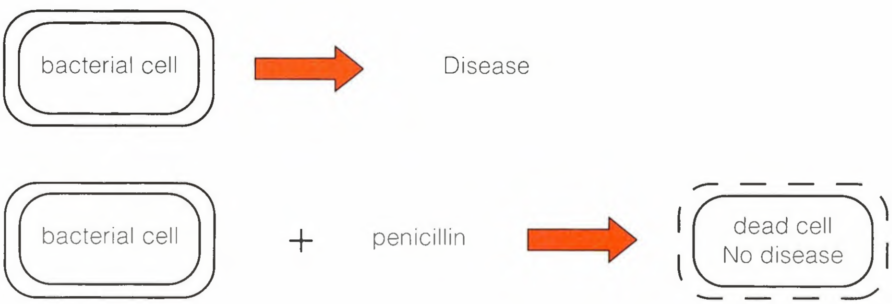
Antibiotics manufacture

In 1929 Fleming discovered that some fungi made chemicals which killed bacteria. No one tried to make or collect these **antibiotic** chemicals. In the Second World War antibiotic production began. It was on a small scale using laboratory flasks. Infected wounds caused death so lots of antibiotics were needed to save lives. Scientists had to find which fungi were easy to keep and which made the most antibiotics.

▶ This is how **penicillin** is produced and collected now.



▼ Penicillin is used for bacterial infections like tonsillitis, pneumonia and septic cuts. It kills bacteria by damaging their cell walls. It cannot kill viruses.



By 1947 penicillin did not work as well. Some bacteria had become **resistant** to it and survived. Some people were **allergic** (had unpleasant side effects) to penicillin. Research is needed to find safer antibiotics and cheaper methods of production. New antibiotics are needed to kill the resistant bacteria and also to kill new bacteria.

Q1 How does penicillin prevent infections?

Q2 What do the fungi need to grow?

Q3 What happens if bacteria get resistant to an antibiotic?

Q4 What type of microbes are not killed by antibiotics?

Q5 Why is research still needed?

Testing antibiotics

Fungi make chemicals called antibiotics which kill bacteria. You are going to find out which antibiotic is best at killing the bacteria called *E.coli*.

Q1 Copy this table.

Dish	Disc	Diameter of affected area (mm)	Appearance of the rest of dish
1	penicillin		
2	streptomycin		
3	paper		

Apparatus

- ☐ 3 labelled Petri dishes of agar and *E.coli* microbes ☐ forceps
- ☐ Bunsen burner ☐ sticky tape
- ☐ marker pen ☐ heatproof mat
- ☐ penicillin antibiotic disc
- ☐ streptomycin antibiotic disc
- ☐ paper disc ☐ eye protection

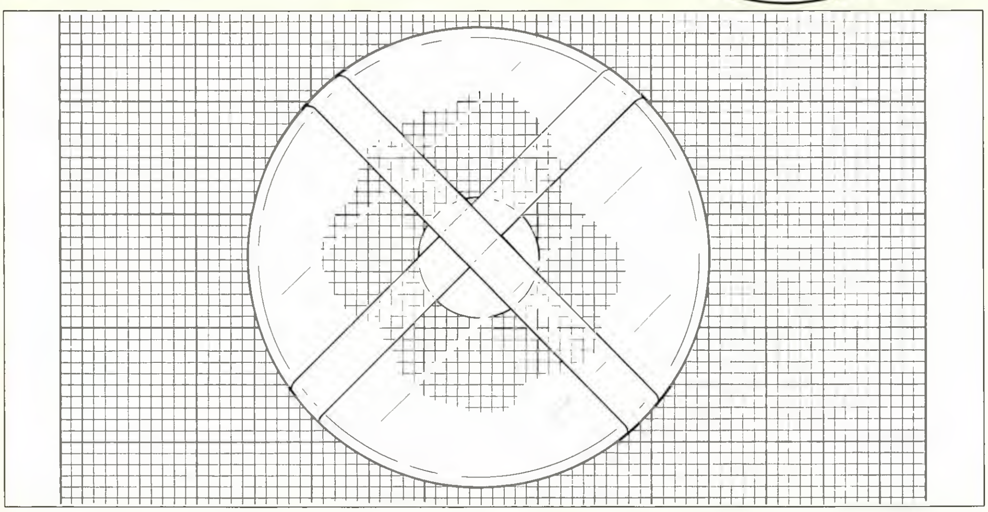
Wear eye protection.

A Label the bottom of each dish with your name, the date and dish number. ▼

B Flame the forceps. Pick up a penicillin antibiotic disc. Lift the lid of dish 1. Place the disc as shown. Quickly close the lid. ▼

C Repeat **B** for dish 2 with the streptomycin disc. Then repeat with the paper disc for dish 3.

D Seal the dishes. Incubate them at 25–30°C for 2–3 days. Then place each dish on a piece of graph paper. Use the squares to measure the diameter of the clear area. Complete your table. ▶



Do not open the Petri dishes. Look at the microbes through the top of the plate.

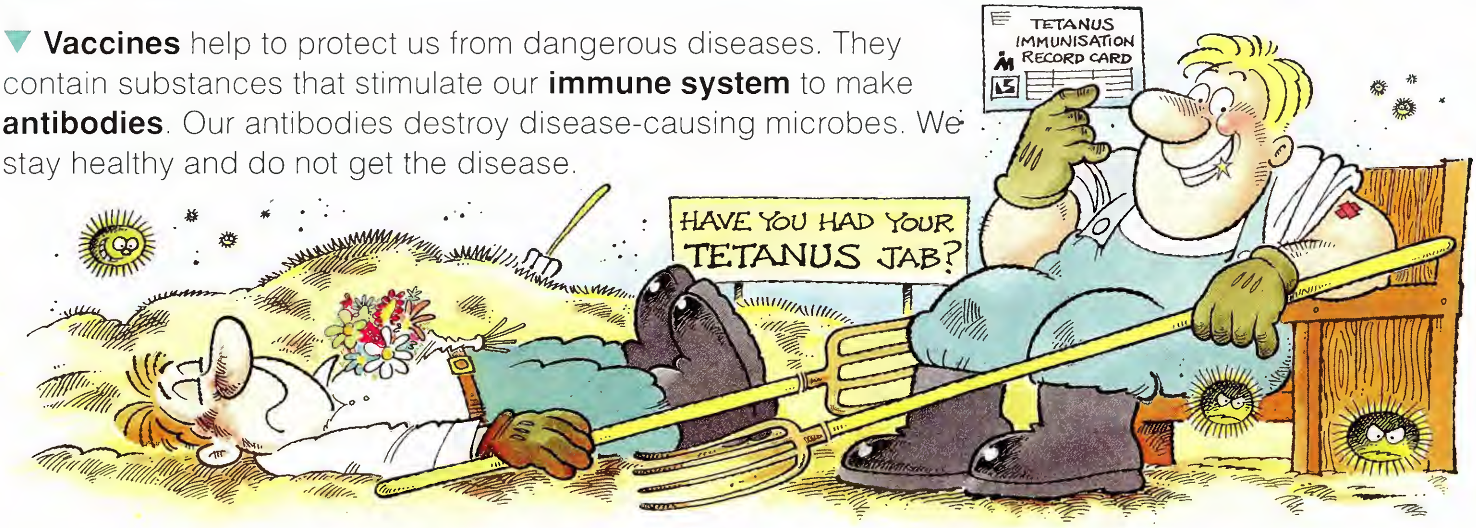
Q2 What was the effect of the antibiotics?

Q3 Why was a paper disc used in dish 3?

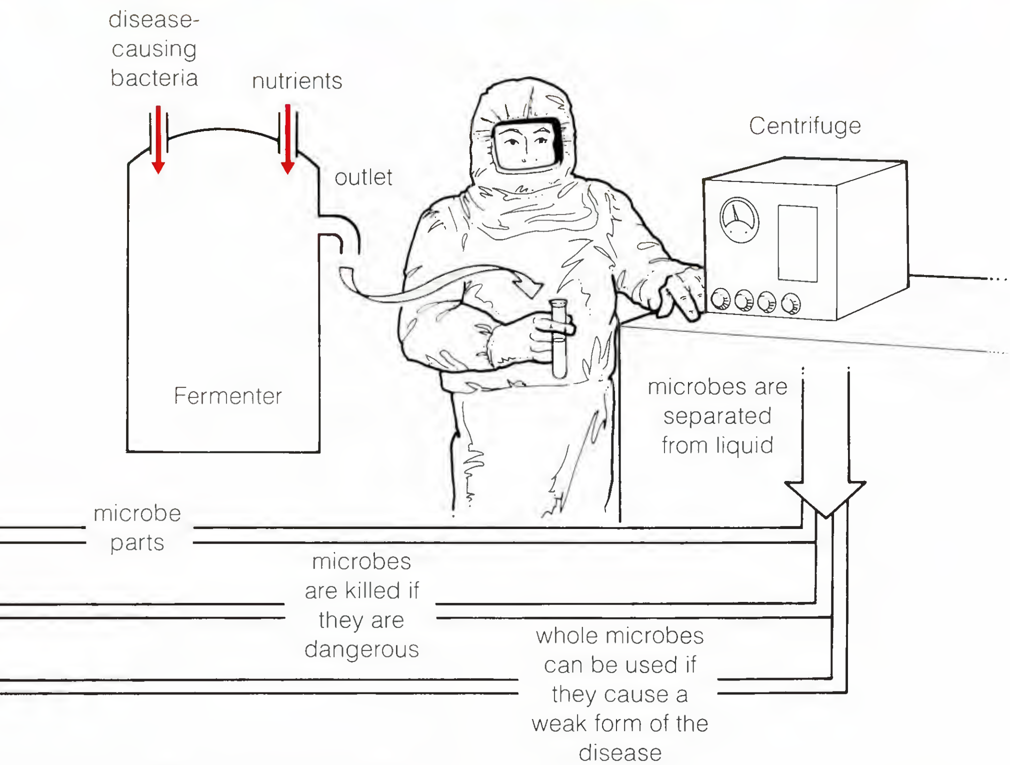
Q4 Scientists have produced many different antibiotics. How could they use this type of test to find the best one to kill the *E.coli* bacteria?

Vaccines

▼ **Vaccines** help to protect us from dangerous diseases. They contain substances that stimulate our **immune system** to make **antibodies**. Our antibodies destroy disease-causing microbes. We stay healthy and do not get the disease.



▶ Smallpox is a deadly disease caused by a virus. Ten million people were infected with it in 1960. Lots of vaccine was needed to save lives. To make the vaccine large numbers of active smallpox viruses were used. Other vaccines are made by growing disease causing bacteria in a fermenter. Workers must be protected from these bacteria. Great care is needed so that workers do not get diseases and become very ill or die.



The anti-smallpox vaccine has been so successful that smallpox no longer occurs anywhere in the world. Polio, rabies and rubella (German measles) can now also be successfully prevented by vaccines.

Q1 Why are vaccines used?

Q2 What do vaccines do for us?

Q3 What do antibodies do?

Q4 How are bacteria separated from the cell suspension?

Q5 What is done to the bacteria to make them safe?

Q6 How are workers protected from the microbes?

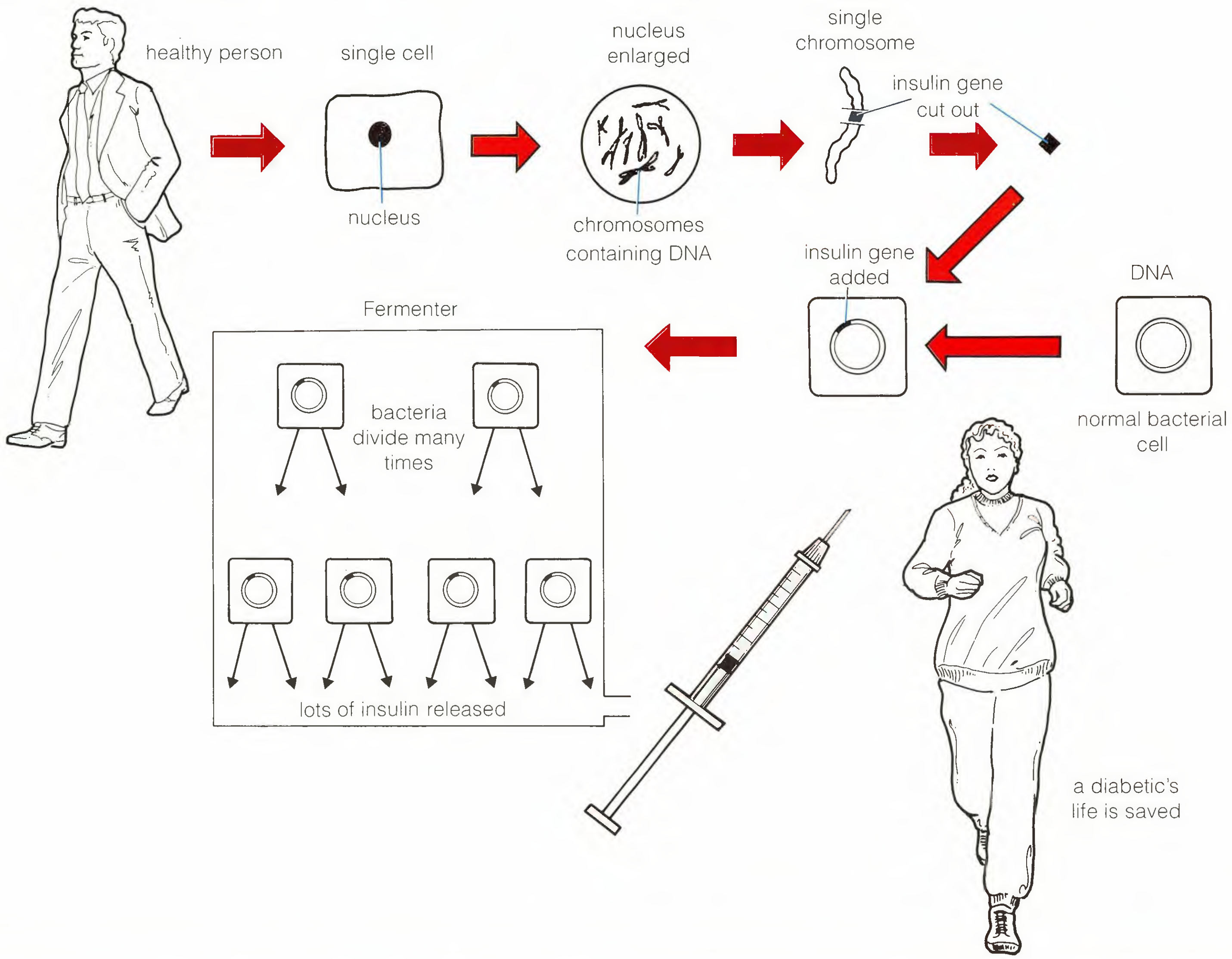
Extension exercise 6 can be used now.

Genetic engineering

Part of our body called the **pancreas** makes **insulin**. Insulin controls how much sugar there is in our blood. A person with too much or too little sugar in their blood goes into a coma (becomes unconscious). Some people have **diabetes**. Their pancreas cannot make enough insulin. Their blood sugar level is not controlled. Without insulin people die. In the past people were given insulin from cattle and pigs. It was difficult to get the amount needed and it was not very good.

Now genetic engineering has produced bacteria which can make insulin. Insulin is a protein. **Genes** control processes like protein production. Genes are found in the nucleus of living cells. Genetic engineering involves removing genes.

▼ The human gene for making insulin has been added to bacteria. These microbes can be kept easily in fermenters. They reproduce quickly and make large quantities of insulin. This product can be removed easily and has saved the lives of many people.



Q1 Why do we need insulin?

Q2 What is genetic engineering?

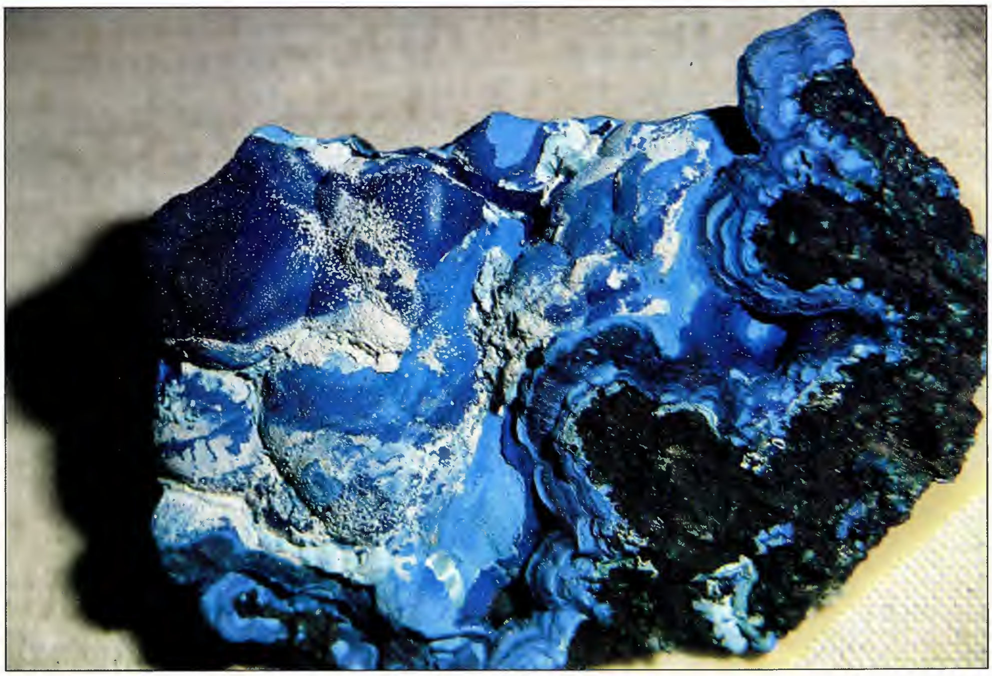
Q3 What sort of microbes have been used to make insulin?

Q4 What is the advantage of using microbes to produce insulin?

Extension exercise 7 can be used now.

6 The chemical industry

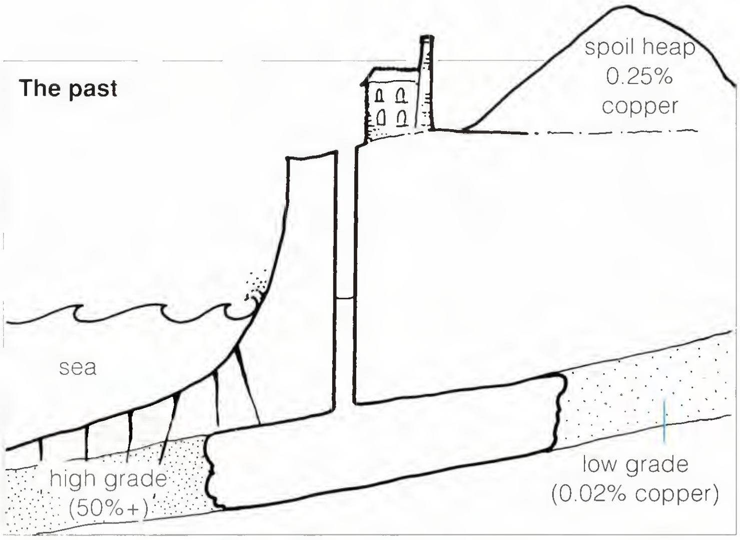
Extracting metals

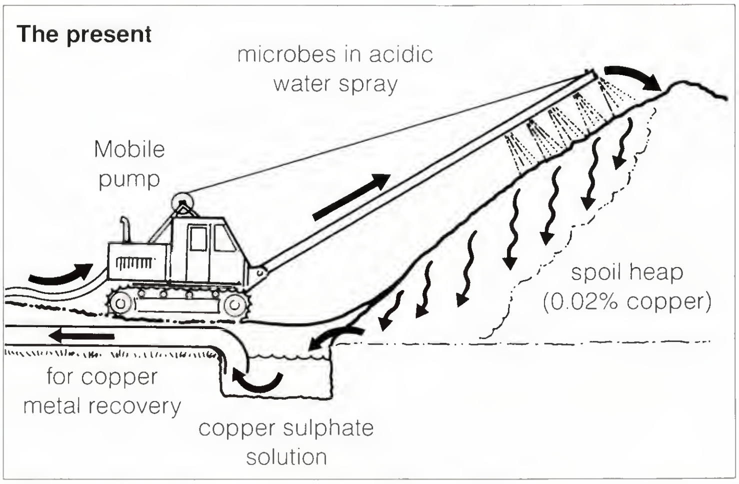


▶ Metals are usually found joined with rock. These substances are called **ores**. High grade ores contain much more metal than low grade ores.

▼ In the past miners removed any easy to mine high grade ores. Low grade ores were left. Their removal cost a lot and little metal was gained. Deep mining was too dangerous. Mines soon closed.

▼ Now supplying all the metals needed is a problem. Little high grade ores are left. They are very deep or in places difficult to mine. **Microbial mining** or **leaching** is a new method of metal extraction. Microbes dissolve metals out of rock, even from low grade ores and spoil heaps. They are cheap and can be used easily in difficult places. Microbial mining is used for copper, uranium, lead, iron, cobalt, nickle, vanadium and gold **extraction**.





Q1 What is an ore?

Q2 What did miners do in the past?

Q3 Why were low grade ores not mined?

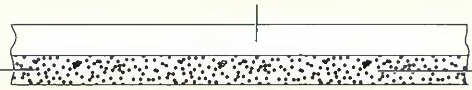
Q4 How can microbes remove metals from rock?

Q5 What are the advantages of microbial mining?

Q6 What metals have been mined with the help of microbes?

Recovering metals

▼ Photographic film contains a **light-sensitive** chemical made from silver. When we take a photograph or an X-ray the film is exposed to light.



Silver is expensive. In this experiment you are going to find out if the protein digesting enzyme, **trypsin**, can recover silver from exposed film.

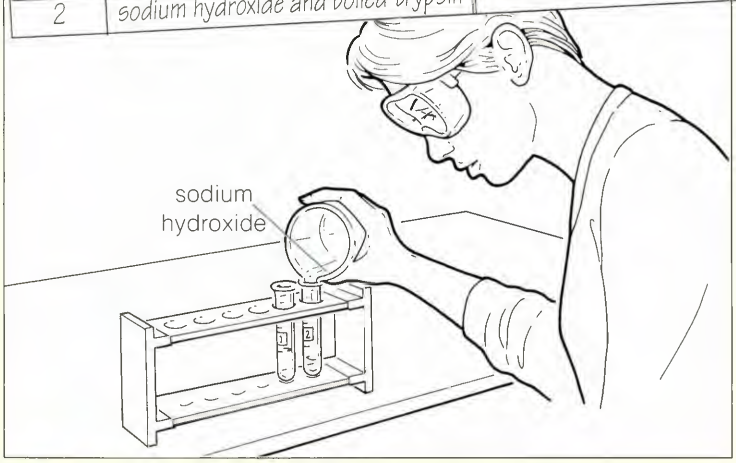
Q1 Copy the table.

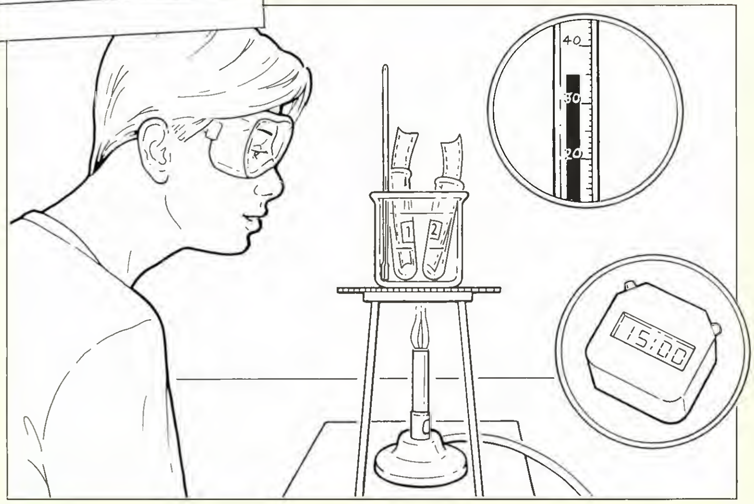
Tube	Contents	Appearance after 15 minutes	
		solution	rubbed film
1	sodium hydroxide and trypsin		
2	sodium hydroxide and boiled trypsin		

Apparatus

- ☐ 2 test tubes marked at 2 and 4 cm^3 ☐ 250 cm^3 beaker
- ☐ test tube rack ☐ marker pen
- ☐ 0–100°C thermometer
- ☐ stop clock ☐ Bunsen burner
- ☐ tripod ☐ gauze ☐ 2 strips of exposed photographic film
- ☐ heatproof mat
- ☐ sodium hydroxide ☐ trypsin
- ☐ boiled trypsin

Wear eye protection.

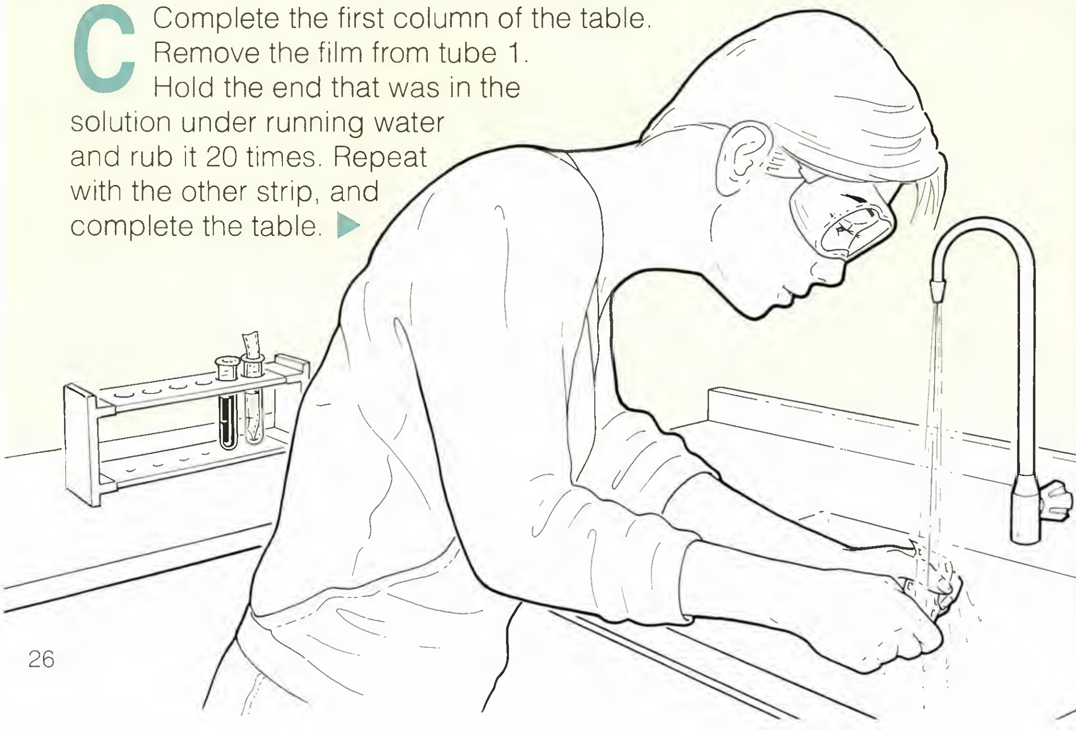




A Label the test tubes 1 and 2. Carefully add 2 cm^3 sodium hydroxide to both tubes. ▲

B Add 2 cm^3 trypsin to tube 1. Add 2 cm^3 boiled trypsin to tube 2. Add a film strip to each tube. Place the tubes in a water bath at 35°C for 15 minutes. ▲

C Complete the first column of the table. Remove the film from tube 1. Hold the end that was in the solution under running water and rub it 20 times. Repeat with the other strip, and complete the table. ▶



Q2 In which tube did the film stay the same?

Q3 Why do you think the liquid turned dark and cloudy when the film was changed?

Q4 Why do people want to recover the silver?

Q5 What shows that it was enzyme activity that removed the silver?

Q6 How could bacteria be made to produce the enzymes needed for recovery of other metals?

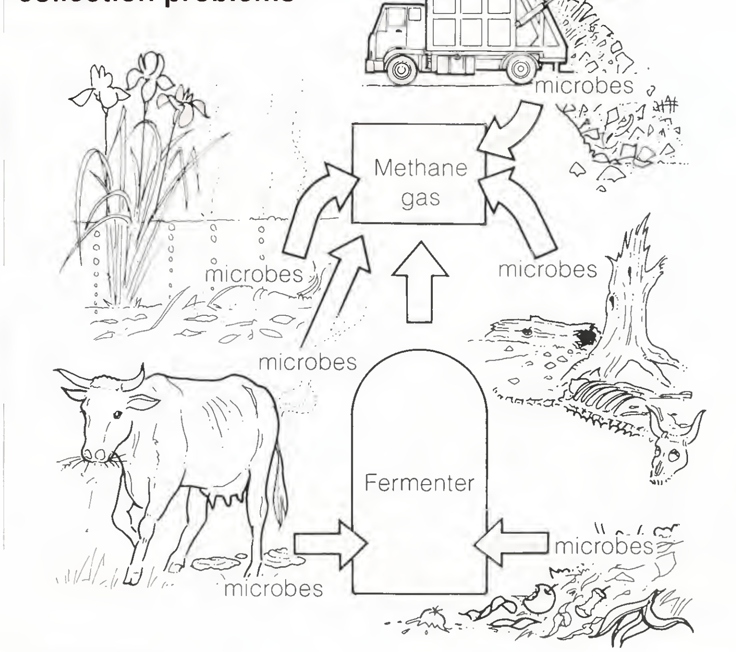
Fuels

▼ Supplies of traditional fuels, like wood, coal and oil, are running out. They are non-renewable. They also cause pollution.

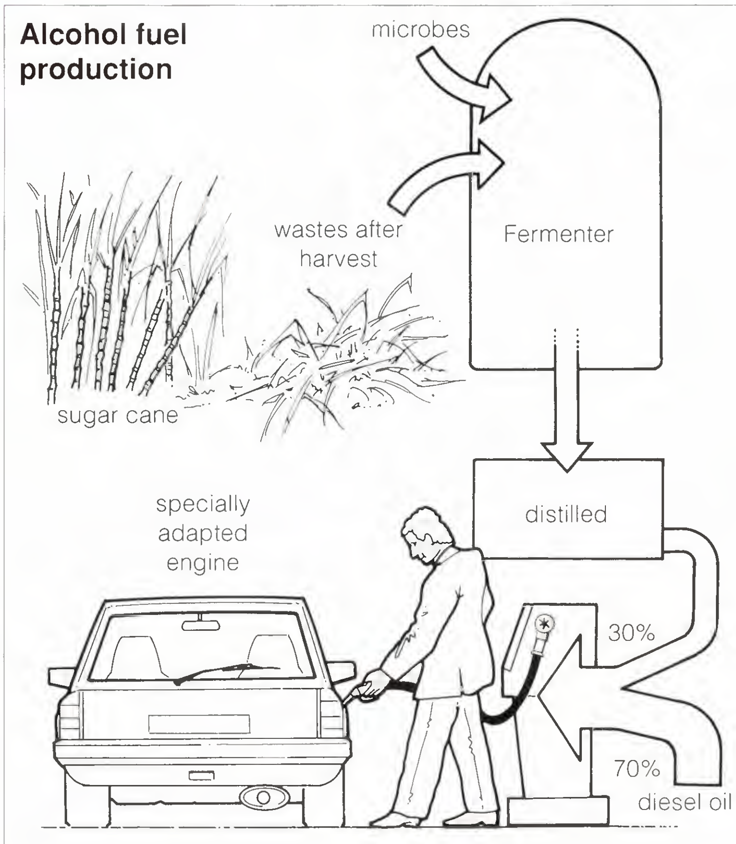
▲ Nuclear fuels may be a danger to the environment. Other alternative sources are safe and renewable but may not be suitable in some areas. Windmills will not work on calm days. Wave machines will not work on lakes.

▼ Microbes can make some fuels, such as methane gas and alcohol fuel. This may be done on a larger scale in the future.

Methane gas production – collection problems



Alcohol fuel production



Q1 What problem is caused by the continued use of traditional fuels?

Q2 What special problems are associated with the use of the most common fuels?

Q3 What is the problem of using nuclear fuels?

Q4 Why do you think that **solar, wave** and **wind** energy are not more popular?

Q5 What are the problems of using the fuels produced with the help of microbes?

7 Using plants

Apparatus

- ☐ house plant ☐ carrot
- ☐ small beaker ☐ disinfectant
- ☐ 2 shallow dishes ☐ water
- ☐ 3 boiling tubes ☐ cotton wool
- ☐ boiling tube rack ☐ knife
- ☐ cutting tile ☐ marker pen

New plants?

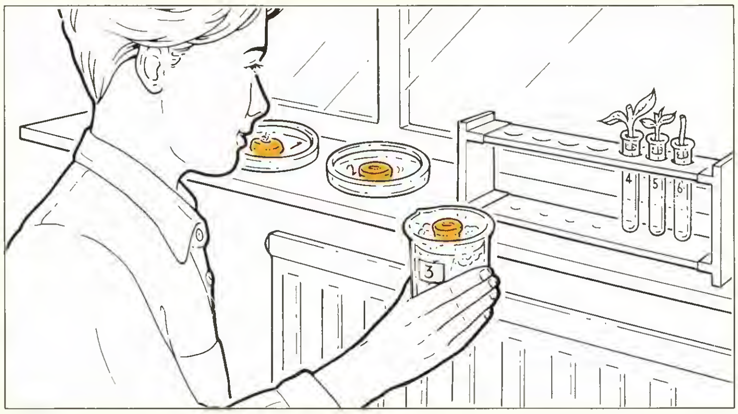
Plants are useful. They provide food and chemicals. People also like attractive flowers. You are going to find out if you can produce new plants.

Q1 Copy the table.

Container	Plant part	Appearance when growth is complete
1	carrot top	
2	carrot middle	
3	carrot bottom	
4	plant top	
5	plant middle	
6	plant root	

A Almost fill the tubes and beaker with water. Half fill the dishes. Label each container with its number, your name and the date. ▲

B Disinfect the knife. Cut three pieces of carrot. Put the top and middle pieces in the correct dish. Use cotton wool to hold the bottom piece at the top of the beaker. ▲



C Disinfect the knife. Cut three pieces from the plant. Remove the lower leaves from the top and middle pieces. Remove upper side roots from the root piece. Use cotton wool to hold each one in the correct tube. ▲

D Leave the containers in a warm, light place. Don't let them dry out. Complete your table when growth is complete. ▲

Q2 Why did you disinfect the knife?

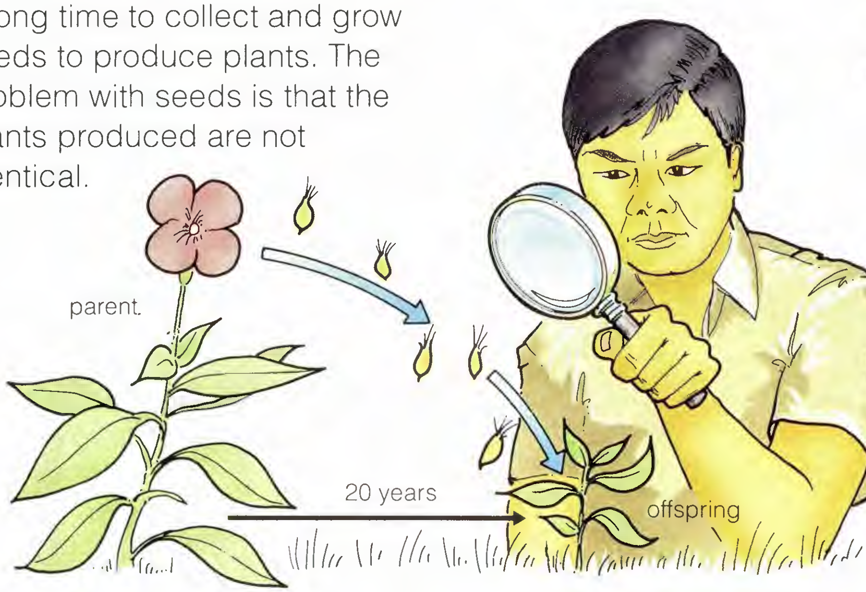
Q3 Which pieces of plant grew best?

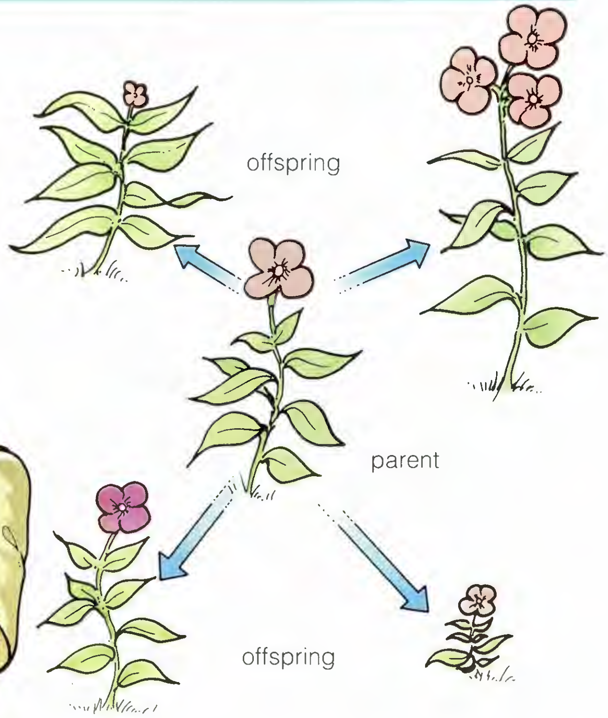
Q4 In time which would produce the best complete plant?

Q5 What problems could a commercial grower have in producing lots of plants?

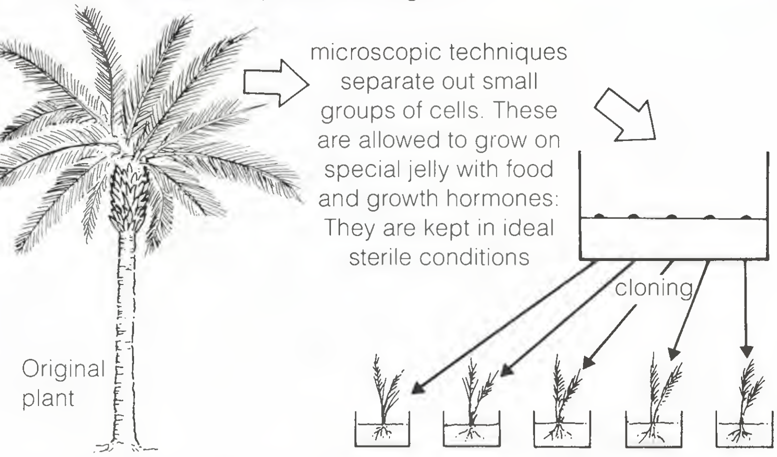
Plant tissue culture

▶ It can take years for some plants to produce seeds. It takes a long time to collect and grow seeds to produce plants. The problem with seeds is that the plants produced are not identical.





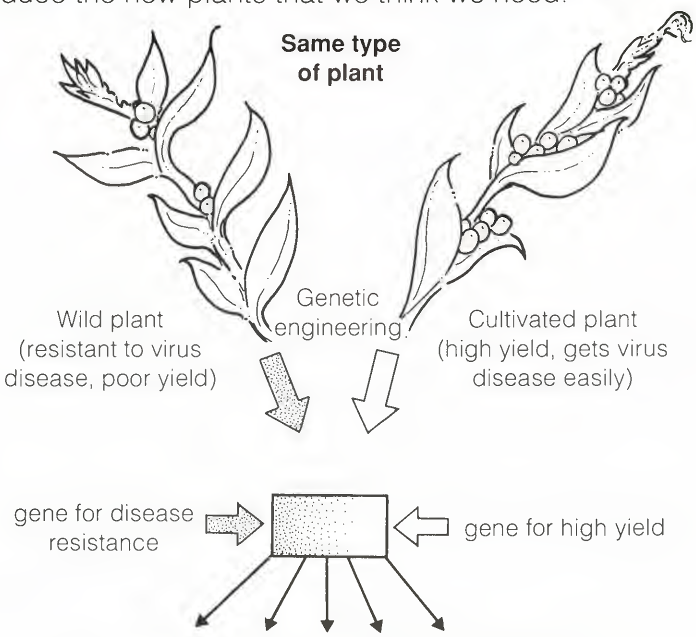
It is important to produce large numbers of identical plants quickly. **Micropropagation** used in **tissue culture** solves the problems of growing difficult plants that are slow or expensive to grow.



thousands of identical small, healthy, germ-free plants are produced quickly.

They are:
- ☐ high yielding
- ☐ disease resistant
- ☐ useful for making valuable products such as food, drugs, flavourings, chemicals, colourings

Genetic engineering may make it possible to produce the new plants that we think we need.



Micropropagation (thousands of plants with the best characteristics of both parents)

Q1 If lots of identical plants are needed what are the problems of collecting seed?

Q2 What do you think micropropagation means?

Q3 Why has genetic engineering been useful?

Q4 How could plant tissue culture be useful to farmers growing food crops?

Q5 Apart from providing food, how else are plants useful?

Algae

Algae are special plants that live in water or in damp places. Most people have seen the largest algae, seaweeds, at the seaside. They are unaware of the many microscopic algae. Have a look at the algae provided.

Apparatus

- ☐ microscope ☐ dropper pipette
- ☐ lamp ☐ mounted needle
- ☐ microscope slides and cover slips ☐ labelled samples of algae

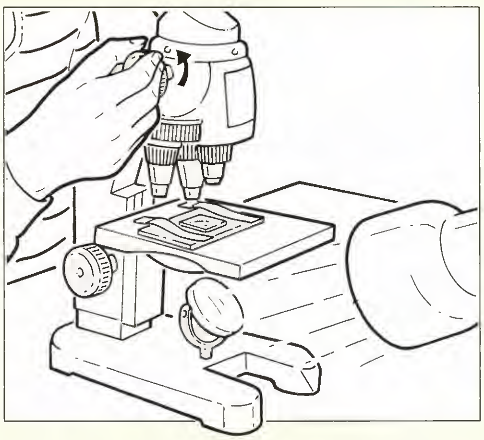
A Set up the microscope on low power. Move the mirror until there is good light. Turn the focusing knob as far as possible as shown. ▼

B Use a clean dropper. Add a drop of the first sample on to a slide. ▼

C Use the mounted needle to carefully lower the coverslip on to your slide, trying not to trap any air bubbles. ▼

D Put your slide on the microscope stage. Slowly turn the knob as shown until your slide is clearly seen in focus. ▼

E Name the algae and describe it. You may draw a diagram to help. Repeat **A** to **E** for each sample.



Q1 Where do algae live?

Q2 What are the largest algae called?

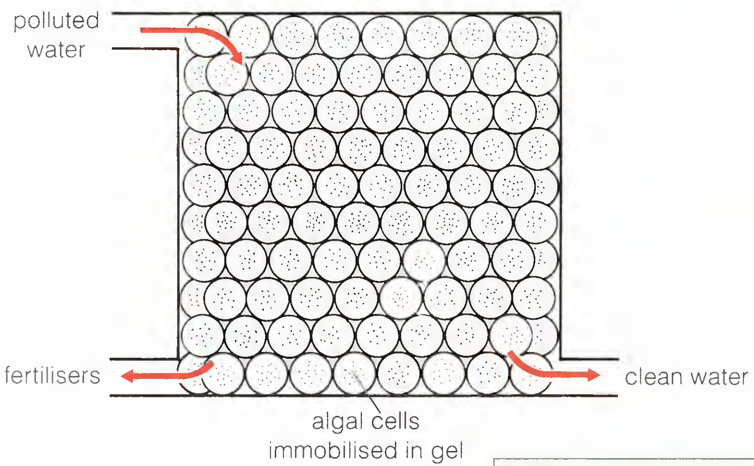
Q3 Ask your teacher how much your microscope magnifies by. Write down the magnification with your drawings.

Q4 What colour were the algae?

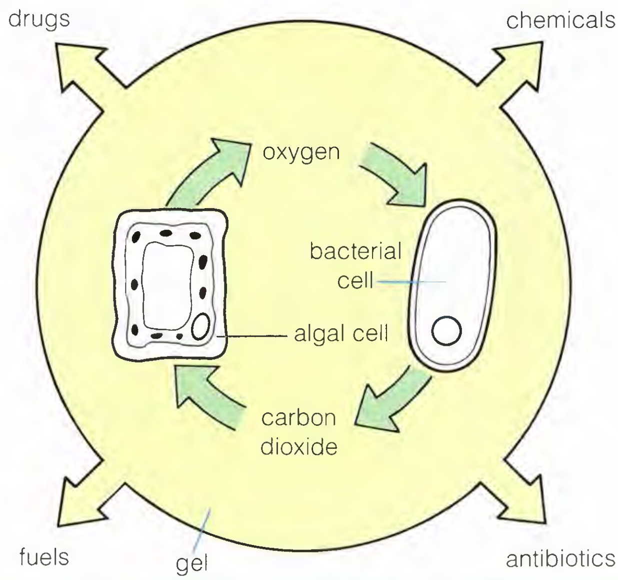
Uses of algae

Green plants like algae make their own food. To do this they need sunlight. We can eat seaweeds. Even the microscopic algae are nutritious. They are the main food of whales. Microscopic algae are not easy to grow in fermenters. They cannot get enough light.

Algae take in dissolved substances from water and use them to make new chemicals. Scientists can 'trap' microscopic algae in a thick gel so that the cells cannot be lost. Months later the **immobilised** (trapped) **algae** still work well. Their useful chemicals and enzymes can be removed easily. Immobilised algae can clean polluted water. They remove the wastes and turn them into chemicals which can be used as fertilisers. Clean water is left.



Algal cells can be immobilised (trapped) with bacteria. They work better together. They help each other to make and release chemicals. Algae may be used in the future to supply our food and to make new drugs, antibiotics, fuels and chemicals.



Q1 Why are algae useful to us?

Q2 Why is it difficult to keep algae in fermenters?

Q3 What products could be made by algae in the future?

Q4 How could **ecologists** use algae to control river pollution?

Extension exercise 8 can be used now.

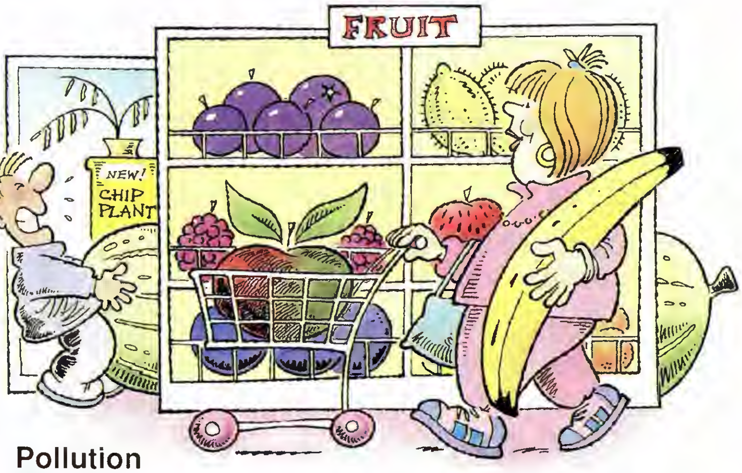
8 The future

Biotechnology in the future

Research in biotechnology may solve present problems.
Our future lives may be very different.

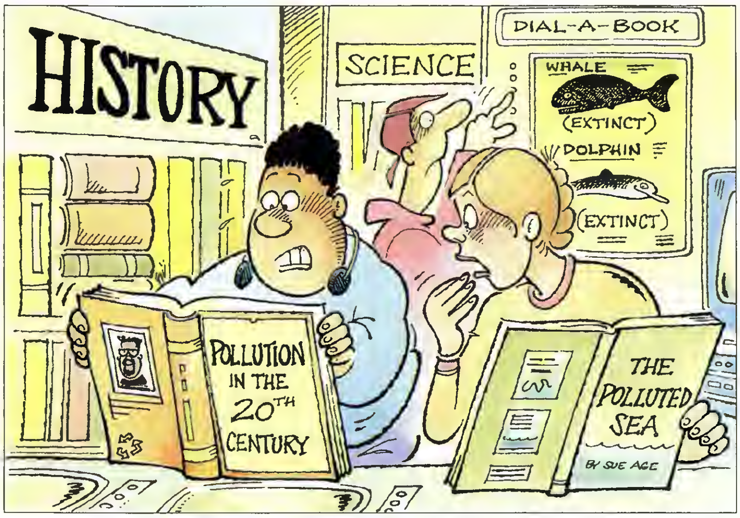
Genetic engineering

Dangerous inherited diseases could be prevented. **Transplants** might be more successful. New antibiotics may cure more diseases. More disease-resistant plants with even higher yields could be produced.



Pollution

More toxic wastes could be destroyed by microbes and converted into useful products. Alternative microbial fuels and sources of energy could be exploited causing reduced pollution.

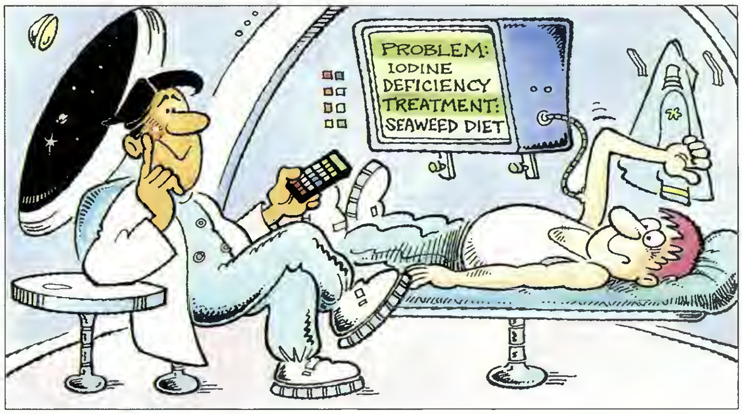


The food industry

New foods could be produced from algae and fungi. Farmers might use microbes to convert plant remains into useful food. Crop yields might be improved by better fertilisers. Growth might be improved by adding nitrate producing bacteria into plant roots.

Future technology

Biosensors could be used to monitor (measure) levels of chemicals in industrial processes more efficiently. They could also help doctors to detect chemical changes inside us. **Biochips** made from specially made proteins might replace silicon chips in computers. Computers could be miniaturised (made small) and implanted into us to give doctors useful information.



Q1 How may pollution be reduced?

Q2 What might be the benefits of genetic engineering?

Q3 What medical advances might be possible?

Q4 How may food production be improved?

Q5 What problems could be caused by future changes in biotechnology?

Biotechnology

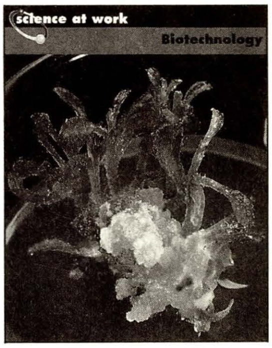
Summary

We hope you have enjoyed this book and have learned some interesting things from it.

We expect you to have found out:
- ☐ how biotechnology can affect your life
- ☐ how living cells are used
- ☐ how enzymes are used
- ☐ how some industrial processes work
- ☐ how our lives may be different in the future.

We expect you to have learned how to:
- ☐ carry out simple experiments with enzymes
- ☐ make some useful food products
- ☐ use some simple practical biotechnology methods.

The cover photograph shows tissue culture. Some cells are placed on special jelly containing food and growth hormones. The Petri dish is kept in ideal conditions. After a short time roots, shoots and leaves appear. Eventually normal, healthy, germ-free plants are grown. All the plants produced in this way from a single plant are identical to the parent.



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