SCIENCE & TECHNOLOGY IN SOCIETY

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SATIS

ABOUT SATIS

Science and Technology in Society units are designed to be used in conjunction with conventional science courses, particularly those leading to GCSE examinations. Each unit has links to major science topics as well as exploring important social and technological applications and issues.

The units are self-contained and generally require about 2 periods (around 75 minutes) of classroom time. Each unit comprises Teachers' Notes (blue sheets) and Students' materials (white sheets). Full guidance on use is given in the Teachers' Notes accompanying each unit, which also include background information and suggest further resources.

Each SATIS book contains ten units. The units are numbered in a system giving the number of the book followed by the number of the unit within that book. Thus the first unit in the first SATIS book is numbered 101.

In addition to the SATIS books, a general Teacher's Guide to the project is available, giving guidance on some of the teaching techniques involved as well as ideas for further activities.

Many people from schools, universities, industry and the professions have contributed to the writing, development and trials of the SATIS project. A full list of contributors appears in the Teachers' Guide.

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SATIS 3

List of units in this book

List of units in the SATIS series

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Air Pollution — where does it come from?

Contents: A data-analysis exercise concerning sources of air pollution.

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

Intended use: GCSE Chemistry, Biology and Integrated Science. Links with work on air pollution, its chemical sources and biological effects. *Note:* extra resources will need to be made available for students to find out the effects of the various pollutants, if this has not been covered in prior lessons.

Aims:

- To complement work on air pollution
- To show the sources of different air pollutants and compare their production by natural and human sources
- To develop awareness that pollutants vary widely in the magnitude of their production and the severity of their effects
- To provide opportunities to practise skills in the analysis and presentation of data.

Requirements: Students' worksheets No. 301. Resources to enable students to find out effects of pollutants (see below).

Notes on some of the questions

Qs. 1 and 2 In school trials it was found that many students had difficulty plotting the bar charts, particularly choosing the right scale. In this revised version of the unit, the job has been made simpler by supplying the axes in Figure 2. However, with able students teachers may prefer to leave the whole job to them, and simply give the students graph paper.

There is no mention in Tables 1 and 2 of carbon dioxide, though it can in some ways be classed as a pollutant because of the 'greenhouse effect'. Teachers may wish to mention this.

Q.3 Sulphur dioxide appears to be the pollutant that is mainly due to human activities. However, it should be noted that hydrogen sulphide is eventually converted to sulphur dioxide in the atmosphere, and this makes the natural and human-made figures for this pollutant of comparable magnitude. Even so, sulphur dioxide still stands out as the major human-made pollutant.

Q.4 Electric power generating stations are the largest source of sulphur dioxide. Its emission can be controlled by using low sulphur fuel or by removing sulphur from fuels before use. This is much more easily done in the case of oil than for coal. The gas can also be removed from flue gases before emission (flue gas desulphurization), though this is expensive.

Q.6 Human-made pollutants upset the natural balance between 'sources' and 'sinks' so that pollutants build up in the atmosphere.

Q.7 The figures in the tables are for the whole world. They take no account of local concentrations of pollutants, which are particularly high in industrial areas.

Q.8 Increasing levels correspond broadly with increasing industrialization in Britain and the accompanying increase in the burning of fossil fuels, particularly coal. The dip in the 1920s and 1930s corresponds to the Depression. The fall since the mid-1960s can be largely attributed to emission control efforts and the increased use of natural gas and other low sulphur fuels, but also to a slowing down of industrial growth.

Further resource materials

Further details of air pollutants, particularly their effects, can be found in a number of standard textbooks — for example:

Chemistry by A. Hunt and A. Sykes (Longman)
Biology for Life by M. B. V. Roberts (Nelson)
Science by Graham Hill and John Holman (Nelson).

More detailed information can be found in, for example:

Air Pollution by W. Strauss and S. J. Mainwaring (Edward Arnold)
'Pollution of the environment' by M. Holdgate, in *Industry: Organization and Obligation,* Science in Society, Book I (Heinemann Educational Books/Association for Science Education).

A useful film on the subject is *The Air my Enemy,* produced by British Gas and available as video or 16mm film. It runs for 25 minutes and can be obtained on free loan from British Gas Film and Video Library, Park Hall Road Trading Estate, London SE21 8EL.

Sources of data

The data in Tables 1 and 2 is taken from W. Strauss and S. J. Mainwaring, *Air Pollution* (Edward Arnold 1984).

The graph showing sulphur dioxide emissions at different dates (Figure 3) is taken from *Acid Deposition in the United Kingdom* (Warren Spring Laboratory 1983).

AIR POLLUTION — Where does it come from?

In this unit you will be looking at the major gases which cause air pollution. What are their sources? How do the amounts produced by humans compare with the amounts of the same gases which are produced naturally?

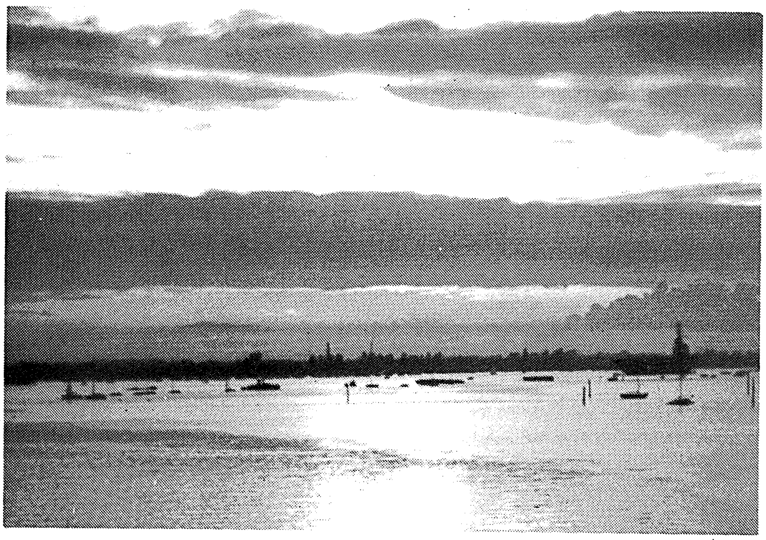


Figure 1 The air looks clean — but is it?

Table 1 shows the sources and amounts of the major air pollutants made by human activities all over the world.

Table 1 Sources of pollutant gases made by humans

Pollutant gas	*Source*	*Amount produced per year throughout the world (millions of tonnes)*
carbon monoxide (CO)	burning of fuels	300
sulphur dioxide (SO_2)	burning of coal and oil, roasting of sulphide ores	146
hydrocarbons	vehicle exhausts, chemical processes	88
nitrogen oxides (NO, NO_2)	vehicle exhausts, burning of fuels	50
ammonia (NH_3)	waste treatment	4
hydrogen sulphide (H_2S)	chemical processes, sewage treatment	3

Table 2 shows the amounts of the same gases made by *natural* sources all over the world. These natural sources have been producing the gases for millions of years.

Table 2 Sources of pollutant gases from natural sources

Gas	*Source*	*Amount produced per year throughout the world (millions of tonnes)*
carbon monoxide (CO)	forest fires, biological processes	3000
sulphur dioxide (SO_2)	volcanoes	9
hydrocarbons	biological processes	1000
nitrogen oxides (NO, NO_2)	bacterial action in soils, electrical storms (lightning flash)	160
ammonia (NH_3)	biological decay	150
hydrogen sulphide (H_2S)	volcanoes and biological decay	65

Questions and activities

1. *Use the figures in Table 2 to plot a bar chart showing the amount of each gas made by natural sources each year. Use the axes on Figure 2 on the next sheet. The bar for carbon monoxide has already been done for you.*
2. *On top of your first bar chart, plot the amounts of each gas from human sources, using Table 1. Show clearly, by colouring or some other method, which is which. The bar for carbon monoxide has already been done for you.*
3. *Compare the values on the bar charts for the different gases. Which pollutant is made much more by human activities than by natural sources?*
4. *In what ways could the emission of this pollutant be controlled so that less is released into the air?*

For millions of years pollutant gases from natural sources have stayed at a steady level in the atmosphere. This is because there are various natural ways that the pollutants get removed from the atmosphere. For example, some of the sulphur dioxide and carbon dioxide are removed from the atmosphere by dissolving in rain.

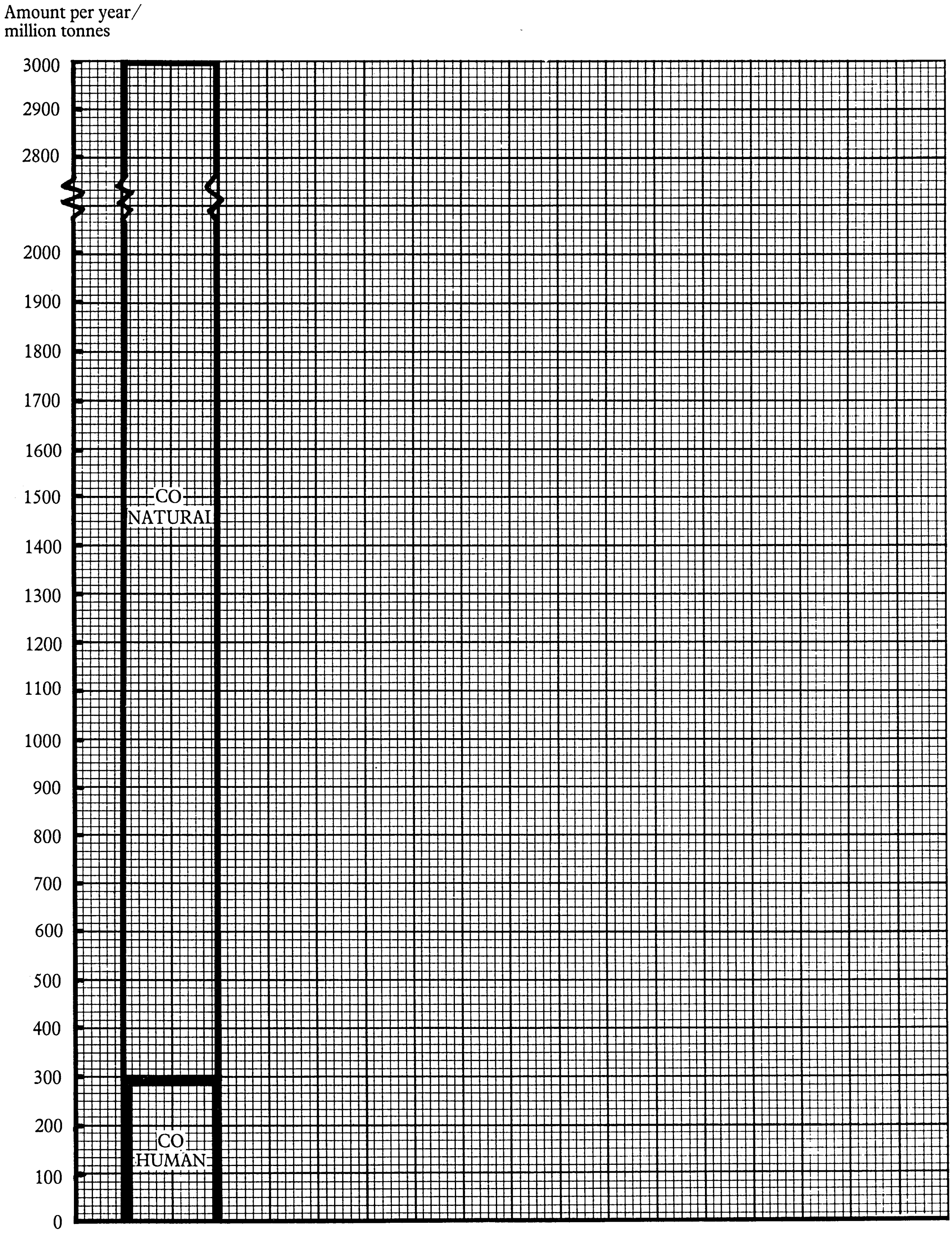


Figure 2 A bar chart showing amounts of different pollutant gases produced per year

Questions

5 *Apart from rainfall, what other process removes carbon dioxide from the atmosphere?*

6 *Even though pollutant gases are removed from the atmosphere naturally, scientists are concerned about adding pollutants made by human activities. Why?*

7 *Judged from the data given in the tables, pollution by humans does not seem to be very serious compared with natural sources. Yet in many cities, particularly in Europe and North America, air pollution is an extremely serious problem. Why?*

Figure 3 shows how the production of sulphur dioxide by human activities in Britain has changed since 1850.

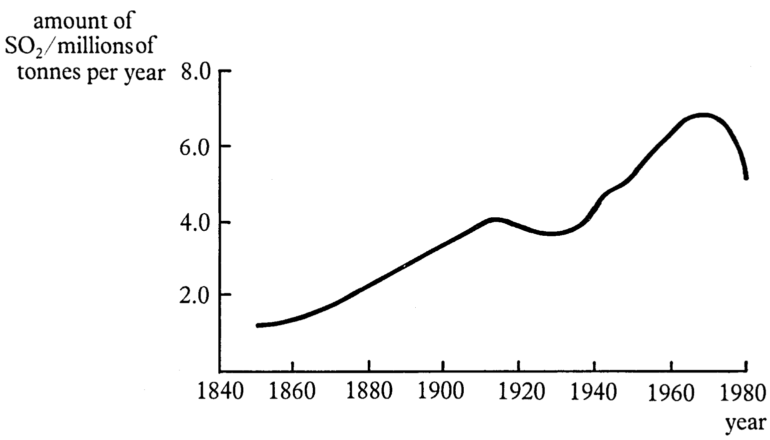


Figure 3 Changes in the production of SO_2 by human activities since 1850

Questions

8 *Suggest reasons why the emission of sulphur dioxide*

(a) rose steadily between 1850 and 1900

(b) dropped in the 1920s and 1930s

(c) rose steeply in the 1940s, 1950s and 1960s

(d) has been falling since the 1970s.

9 *All pollutants have harmful effects. For as many of the pollutant gases as you can, find out some of their harmful effects.*

Living with Kidney Failure

Contents: A structured discussion concerning the treatment of kidney failure and some of the related problems.

Time: 2 periods plus homework.

Intended use: GCSE Biology or Integrated Science. Links with work on the kidney and homeostasis.

Aims:

- To complement and revise prior work on the kidney
- To outline the nature of kidney failure and the methods for its treatment
- To develop awareness of, and sympathy for, some of the medical, economic and human problems associated with kidney failure
- To develop awareness of problems associated with the allocation of limited resources in the National Health Service
- To encourage readiness to enter into discussion.

Requirements: Students' worksheets No. 302:
For each member of the class:
1 copy of General Briefing (sheet GB)
1 copy of Test (sheet T)

For each group of four students:
1 copy of each of the Expert's Briefings (sheets EB1, EB2, EB3)
1 copy of the Chairperson's Briefing (sheet CB)

This unit is best used after a conventional lesson or lessons on the kidney. The information on the structure and working of the kidney in the General Briefing is highly simplified and makes no mention of the complex procedure of selective reabsorption.

Procedure

1. Give each student a copy of the General Briefing (sheet GB). Allow them time to read and study it — this is best done for homework preceding the lesson.
2. Get them to do the test. This should take no more than 10 minutes. Go through the answers.
3. Form the class into groups of four. Each group should have a Chairperson, chosen for his or her potential for leading a discussion. If the class does not divide neatly into groups of 4, have some groups of 5.
4. Give the Chairperson their Briefing (sheet CB). Give Expert's Briefings (sheets EB1, EB2, EB3) to the other three members of the group — a different sheet to each member. If any groups have 5 members, sheet EB1 could be given to two people. Allow them time to study the briefings.
5. Hand over the running of the group discussions to the Chairpersons. Avoid intervening if possible.

This structured approach to the discussion should help increase students' commitment to the work. However, if the teacher wished, the unit could be used more conventionally by giving students copies of all the sheets and getting them to read the briefings, then answer the questions in the Chairperson's Briefing.

Note that the costing of kidney treatment is difficult, and estimates of cost vary widely. The figures given in sheet EB3 are at 1984 prices.

No mention has been made in the students' materials of peritoneal dialysis. This method employs the peritoneum as a natural body membrane for dialysis, and is quite commonly used, though less so than kidney machines or transplants.

Other resources

The following organizations are sources of further information about kidney treatment:

British Kidney Patient Association, Bordon, Hampshire

European Dialysis and Transplant Association, St Thomas's Hospital, London SE7 7EH

Acknowledgements Figures 1 and 2 (General Briefing) are reproduced by permission from *Science* by Graham Hill and John Holman (Nelson); Figure 3 (General Briefing) supplied by the British Kidney Patient Association; Figure 2 (Expert's Briefing 1) is adapted from *Revised Nuffield Advanced Biology Study Guide 1* (Longman).

Living with Kidney failure

General Briefing

Kidneys and kidney failure

What do the kidneys do?

The job of the kidneys is to purify the blood. As it travels around the body, the blood collects waste products such as urea. It also collects excess water. The kidneys remove the waste and excess water so they can be passed out of the body as urine.

Figure 1 shows the human urinary system. You can see there are two kidneys, one on each side of the body, just above the waist.

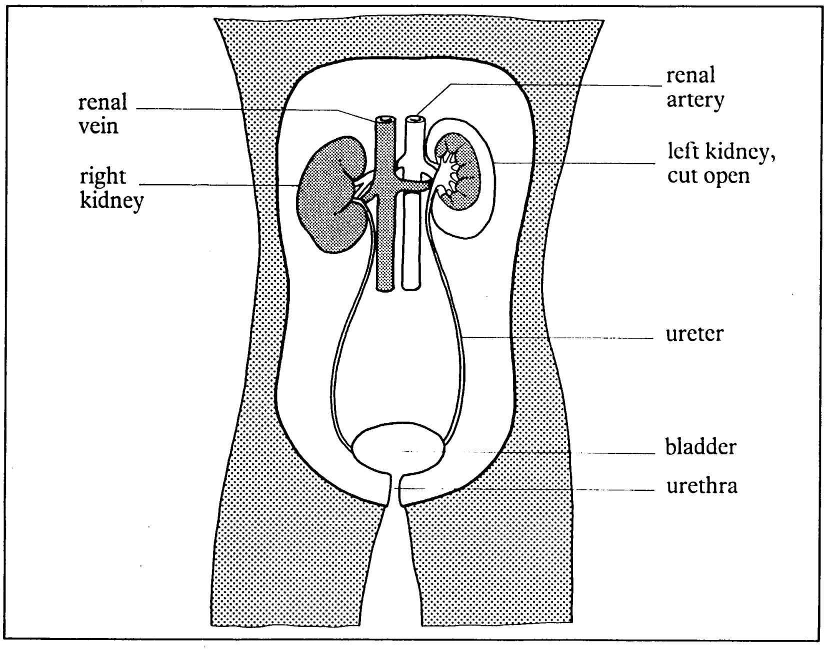


Figure 1 The human urinary system

Each kidney has a rich blood supply. About a litre of blood flows through the kidneys each minute (Figure 2).

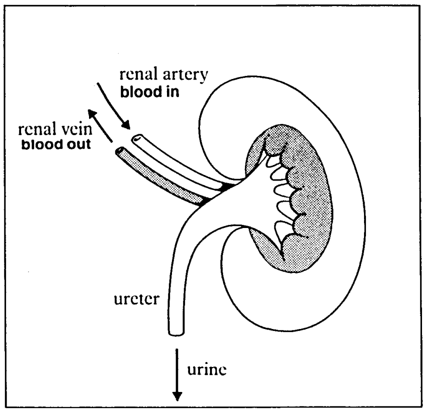


Figure 2 Detail of a kidney's blood supply

In some ways the kidneys act like filters, filtering out harmful waste substances from the blood. However, the process is much more complicated than simple filtration. For one thing, the waste substances are soluble in water, so they cannot be filtered off in the usual way. For another thing, the kidneys have to remove excess water from the blood as well as waste.

What can go wrong with the kidneys?

Sometimes stones form in the kidneys. They do not stop the kidneys working, but they can be painful and they may cause blockages.

Sometimes a kidney may stop working completely. This is called **kidney failure.** It may happen because the kidney has been damaged, or because of an infection. If only one of the kidneys fails, the other can manage on its own. But if both fail, the patient will be poisoned by his or her own waste products. If patients are not treated quickly they will die.

How can kidney failure be treated?

In Britain several thousand people have kidney failure each year. Until the 1960s it was not possible to treat them, and they usually died. But in recent years, doctors and scientists have developed two ways to deal with kidney failure:

1 **Kidney machines** — artificial kidneys which the patient must use two or three times a week (more details in Expert's Briefing 1)
2 **Kidney transplants** — a healthy kidney is transplanted into the patient's body (more details in Expert's Briefing 2)

Why do people still die from kidney failure?

Some people suffering from kidney failure are ill in other ways as well. They may have diabetes, or very high blood pressure. These complications may make it difficult to treat them on a kidney machine or to give them a transplant.

But over 1500 people who *could* be treated die from kidney failure in Britain each year. This is because the cost of giving transplants and running kidney machines is very high. There are not enough kidney machines to treat everyone. Expert's Briefing 3 gives more information about this problem.

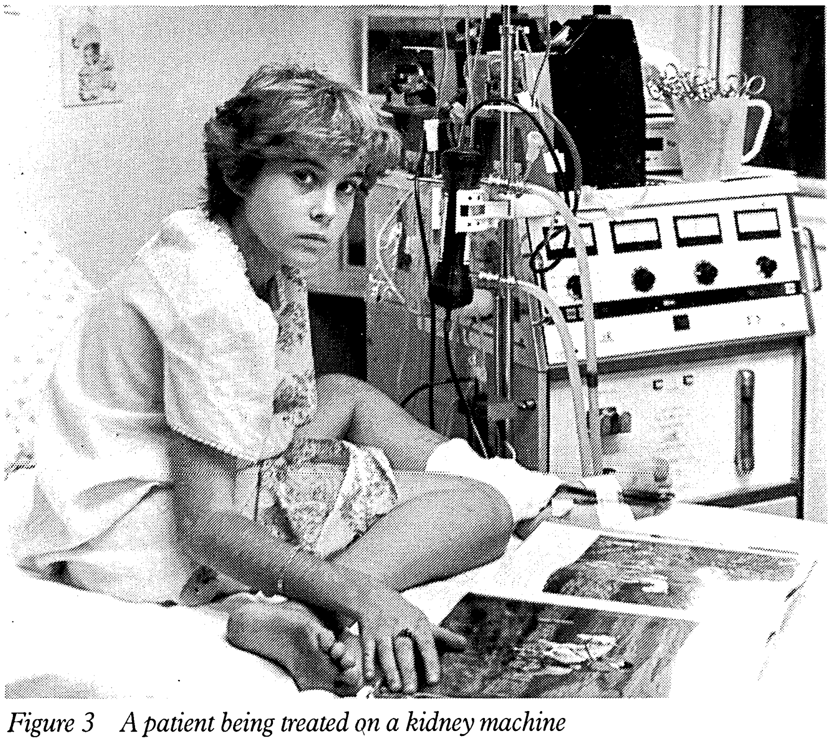


Figure 3 A patient being treated on a kidney machine

Test on kidneys and kidney failure

1 What important job in the human body is done by the kidneys?

2 Why do the kidneys need to have a rich blood supply?

3 Kidneys produce urine. What does urine contain?

4 Give two causes of kidney failure.

5 Why will a person with kidney failure die unless he or she is treated?

6 What are the two major ways of treating kidney failure?

Living with Kidney Failure: Expert's Briefing 1

What are kidney machines?

You will shortly be taking part in a group discussion on kidney treatment. You are the only one in your group who has read this sheet, so you will be the expert on kidney machines. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words.

Kidney machines work in a similar way to real kidneys. The patient's blood flows on one side of a very thin membrane. On the other side, a watery solution called a **dialysate** flows.

Impurities from the blood pass across the membrane into the dialysate. This is called **dialysis**. It is important to stop *useful* substances, like sugar and some salts, passing out of the blood along with the impurities. To stop this happening, the dialysate has sugar and salts dissolved in it. Their concentration is the same as the normal concentration of sugar and salts in the blood. In this way, these useful substances are prevented from leaving the blood. Figure 1 shows the basic idea.

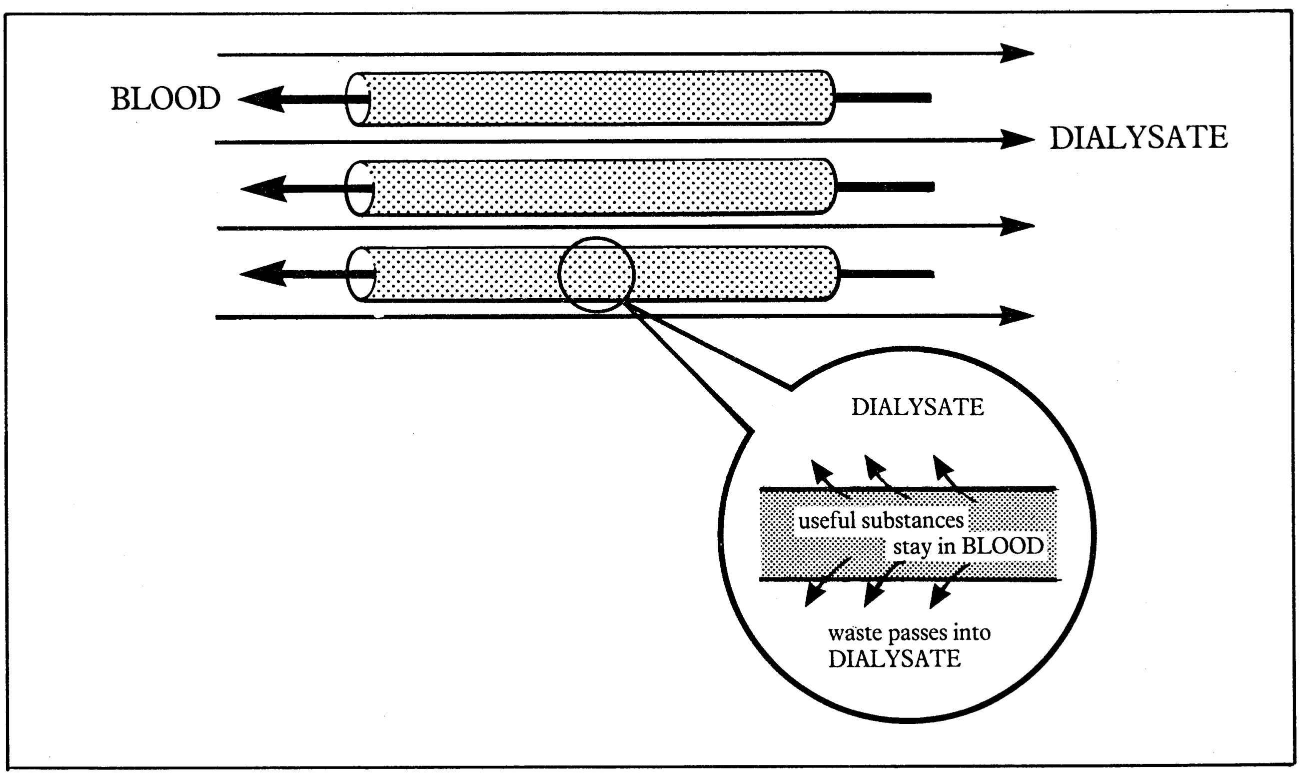


Figure 1 How dialysis works

The patient has to be connected to the machine for ten hours or so, two or three times a week. Blood from an artery, usually in the arm or leg, flows into the machine. After passing through the machine and getting cleaned, the blood flows back into a vein. The blood has to pass many times through the machine to get rid of all the waste. This is why the patient must stay connected to the machine for about ten hours. The patient's blood is collected through a hypodermic needle inserted into a vein in the arm. Blood is returned through another needle inserted in the same vein (Figure 2). The vein is a specially large capacity one, made surgically by connecting a normal vein to an artery.

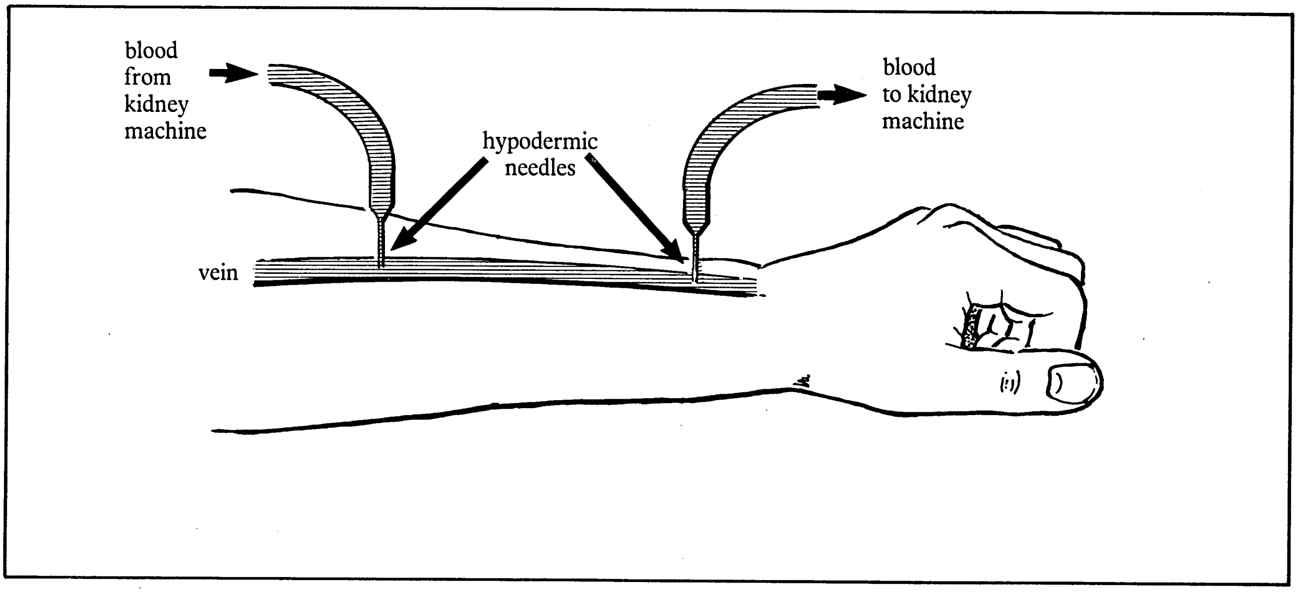


Figure 2 Connecting a patient to a kidney machine

Some kidney patients have their own kidney machine at home. Others go into a hospital or treatment centre each time they need dialysis.

Kidney machines save lives, but they can bring problems. Life can be difficult and restricted because dialysis takes up several hours a week, each week of the year. Patients sometime suffer medical problems such as anaemia and infections, bone disease and loss of sexual drive. They have to follow a careful diet. The diet cuts down particularly on foods which produce a lot of waste products like urea. The only time the patient can eat these 'forbidden foods' is when they are connected to the machine.

Living with Kidney Failure: Expert's Briefing 2

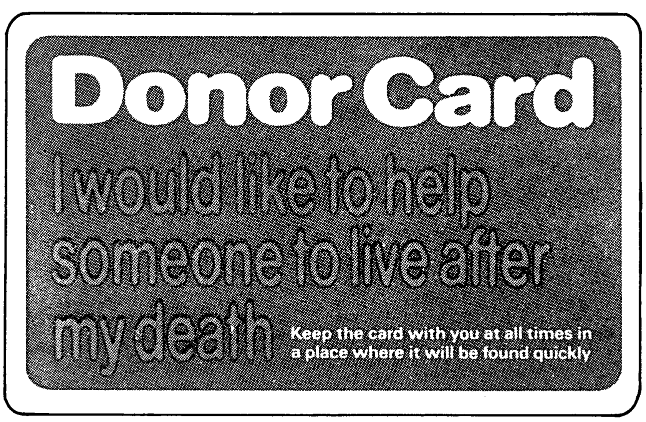
What are kidney transplants?

You will shortly be taking part in a group discussion on kidney treatment. You are the only one in your group who has read this sheet, so you will be the expert on kidney transplants. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or women in the street' might ask. Try to answer them as simply as possible, in your own words.

Sometimes, doctors can replace a failed kidney with a healthy one, taken from a human **donor**. This is a **kidney transplant**. The kidney may come from a live donor or from a person who has just died.

Live donors We have two kidneys, so one can be donated. This is most commonly done by relatives. The chances of a kidney being rejected by the patient's body are less if the kidney comes from a close relative. However, only about 12 per cent of transplant kidneys come from live donors.

People who have just died To be of any use, the kidneys need to be 'alive' when they are taken from the donor's body. They must be removed within an hour of death, and used within twelve hours.



I request that after my death
*(a) my *kidneys, *eyes, *heart, *liver, *pancreas be used for transplantation; or
*(b) any part of my body be used for the treatment of others
*(delete if not applicable)

Signature Date

Full name (block capitals)

In the event of my death, if possible contact:

Name Telephone

Figure 1 A Donor Card (front and back)

The best kidneys come from young, healthy donors. Often, these are people who have been killed in road accidents.

Kidneys cannot be taken from a person's body without permission from close relatives. However, some people carry a signed Donor Card (Figure 1). This gives permission for their kidneys and other organs to be used in transplants.

Problems with kidney transplants

Shortage of donors There are not enough donated kidneys available to allow every suitable patient to have a transplant. This is partly because there is a shortage of donors. Even where a donor is found, the kidneys can often not be removed quickly enough after the person has died.

Rejection Unless the new kidney comes from an identical twin, it will not match the patient's own body perfectly. Doctors try to match the new kidney as closely as possible, for example, by taking it from a close relative like a sister or brother. Even so, the body is bound to **reject** the kidney to some extent. Transplant patients are given medicines to control the rejection, but these medicines may have unpleasant side-effects.

If there is serious rejection of the kidney, the patient may have to have another transplant.

Living with Kidney Failure: Expert's Briefing 3

Statistics about kidney treatment

You will shortly be taking part in a group discussion on kidney treatment. You are the only one in your group who has read this sheet, so you will be the expert on statistics about kidney treatment. After you have read this, the Chairperson of your group will be asking the kind of questions a 'man or woman in the street' might ask. Try to answer them as simply as possible, in your own words. Your briefing is quite short but you have a calculation to do before the discussion starts.

Proportions of patients on different kinds of treatment

Between a quarter and a third of kidney failure patients are treated by transplants. The remaining patients, if they receive treatment, are treated by kidney machines. More than half of kidney machine patients have treatment at home.

Cost of treatment

Treatment for kidney failure is very expensive. The figures given here are approximate:

1 The cost of a *transplant* is around £6000 for the operation. Follow-up treatment costs around £1800 per year.

2 For kidney machine treatment in hospital, the cost is around £12 000 per patient per year.

3 For kidney machine treatment at home, the cost is around £7500 per patient per year.

Calculation

Work out the cost of keeping a kidney patient alive for three years by each of the treatment methods given above. You should assume the transplant works first time, though this is not always true.

For most patients these costs would have to be paid by the National Health Service.

Living with Kidney Failure: Chairperson's Briefing

You are the chairperson of a group of students. It is your job to ask questions and chair a discussion on kidneys and kidney failure. Much of the success of the session will depend on how well you do your job.

Everyone in your group will have read the General Briefing. Each member (except for you) will also have read an Expert's Briefing. The Expert's Briefings are:

1 What are kidney machines?

2 What are kidney transplants?

3 Statistics about kidney treatment.

You will begin by asking some specific questions about treatment of kidney failure. These questions will probably be answered by one of the Experts, though you should allow others to answer if they want. *Try to act as a 'man or woman in the street' who is trying to find out about kidney treatment.* Encourage the Experts to answer in their own words — don't let them read out from the Briefing sheets! Let the Experts draw diagrams, on an overhead projector, a blackboard or on paper, if they want.

After the specific questions, you will raise some general points for discussion. By this time, if the specific questions have worked properly, your group should have a reasonable idea of the facts behind kidney treatment. Try to encourage everyone to enter into the discussion.

Specific questions

(The number after each question refers to the Expert who is most likely to know the answer)

1 *How does a kidney machine work? (1)*

2 *What do patients have to do when they go for treatment on a kidney machine? (1)*

3 *What is a kidney transplant? (2)*

4 *Where do kidneys for transplant operations come from? (2)*

5 *Why do kidney transplant operations sometimes fail? (2)*

6 *Most kidney patients would prefer a transplant, if they could get one, to treatment on a machine. Why is this? (1,2 or all)*

7 *What proportion of kidney patients get transplants? (3)*

8 *Why can't everyone who wants a kidney transplant have one? (2)*

9 *What are the costs of different ways of treating kidney failure assuming the patient survives three years from the time treatment starts? (3)*

10 *What proportion of kidney machine patients are treated in their own homes? (3)*

11 *Why is home treatment preferable to going to a hospital kidney unit? (1,3 or all)*

General points for discussion

Encourage everyone to take part.

- How would your life be affected if you had kidney failure and had to go on a machine several times a week?
- At present, there are not enough kidney machines in Britain to treat everyone who is suffering from kidney failure. Why is this?
- To provide enough kidney machines would cost the National Health Service money. Where should this money come from? Possibilities are:
  (a) By spending more money on kidney machines and less on other parts of the Health Service
  (b) By spending a bigger *total* amount of money on the Health Service. This would mean increasing taxes, or cutting other services like education.
- If you think the best answer is to spend less on other parts of the National Health Service, which parts do you think should be cut?
- Doctors sometimes have to turn away people who need kidney treatment because there are not enough kidney machines. This may mean these people will die. How should a doctor decide who to treat and who to turn away? Factors which doctors have to consider include:
  (a) Whether the patient is suitable for treatment
  (b) Whether treatment will help the patient
  (c) Whether the patient has dependents, such as a family
  (d) The age of the patient.
- How can we overcome the problem of shortage of transplant kidneys?
- Which members of the discussion group would be prepared to carry a Donor Card?
- Which members of the group would be happy to leave parts of their body for medical experiments as well as transplants?
- At present the law says parts of people's bodies should not be used for transplants unless permission has already been given by the close relatives, or on a Donor Card. Should the law be changed so that *everyone's* kidneys were available, unless relatives or a Donor Card said no?

Physics and Cooking

Contents: Information, recipes and questions relating to some of the physical principles involved in cooking.

Time: If recipes are used: 3 homework sessions and one classroom period for follow-up. If recipes are not used, the unit could be done in class in about 2 periods.

Intended use: GCSE Physics and Integrated Science. Links with work on heat transfer, insulation and microwave radiation.

Aims:

- To complement and revise prior work on heat transfer
- To show that scientific principles are applicable outside the laboratory in such everyday activities as cooking
- To develop willingness to look for scientific patterns and principles in everyday situations
- To provide opportunities to practise skills in reading, comprehension and cooking.

Requirements: Student's worksheets No. 303. The requirements for the recipes are given in the worksheets.

If possible, students should try out the recipes for themselves, if they are not already familiar with them. The unit lends itself particularly well to homework. Naturally there are good opportunities for links with the home economics department.

Notes on some of the questions

Within each part of the unit, the questions are in approximate order of difficulty, with the easiest first.

Q.6 The table below shows how the boiling point of water changes due to the lower pressure at high altitudes.

Height above sea level/m	*Boiling point of water/°C*
0	100.0
250	99.2
500	98.3
750	97.5
1000	96.7

As an optional extra, students might be asked to plot a graph of these figures, and perhaps use it to work out the boiling point of water at the altitude of their school/home (found from a local map).

In high altitude countries such as Tibet, where the boiling point of water may be as low as 90°C, cooking by boiling is noticeably slow, unless pressure cookers are used.

Q.9 The poor thermal conductivity of sponge cakes and other air-filled foods is of considerable importance in cooking. Students should be able to relate this to the insulating properties of expanded polystyrene, birds' feathers, clothing, etc.

Q.10 It is fairly simple to relate the rising of a cake to the expansion of gas bubbles in the mixture, but students may find it harder to see that the bubbles will collapse if the cake is taken out of the oven before the sponge mixture has become hot enough to set and support the bubbles. The setting of sponge mixture is due to the gelatinization of starch (in the flour) and denaturation of protein (in the eggs).

Q.12 Most microwave cookers have a microwave source at the top, together with a 'paddle' which reflects the rays so they come from varying directions.

Cakes do not cook particularly well in microwave ovens because of their low water content. The cake often has a hard, dry texture and rises poorly by comparison with conventionally cooked cakes. Adding extra water to the mixture helps.

Qs 13 to 16 The trick with Baked Alaska is to ensure sufficient thickness of insulating meringue and sponge to prevent significant heat transfer to the ice cream. A high baking temperature ensures quick browning of the meringue.

Further questions

Interested classes might like to tackle further questions, for example:

1 Why do kebabs cook faster on metal skewers than on wooden ones?

2 Why is the top of an oven the hottest part?

3 Why, when you eat apple crumble, does the apple seem hotter than the crumble?
This can be related to (a) the lower thermal conductivity of crumble, and (b) the higher specific heat capacity of apple. The higher specific heat capacity of apple is due to its higher water content. The values below are in $J\ kg^{-1}\ K^{-1}$:

water	4200
apple	about 3700
crumble	about 2900

4 Roasting instructions for two joints of beef:

Mass / kg	*Oven temperature / °C*	*Cooking time / min*
1.5	180	60
3.0	160	140

Why is the larger joint
(a) roasted at a lower temperature,
(b) roasted for longer?
(Both thermal conductivity and heat capacity are important here.)

5 How does a meat thermometer work?

6 Why does food burn (or 'catch') more easily when heated in a cheap, thin saucepan than a heavy, thick-based pan?

Other resources

The Nuffield Home Economics course (published by Hutchinson) is an excellent source of information and activities relating to the scientific principles of cooking.

Practically any recipe from a cookery book is a source of ideas to illustrate scientific principles.

PHYSICS AND COOKING

Boiled eggs, sponge cake, Baked Alaska — you may have enjoyed all these at different times. But like all cooked food, they depend on the skill of the cook.

Cooks perform fantastic feats of physics. They make instant estimates of thermal conductivity and heat capacity. They are geniuses at controlling the transfer of heat for the complex chemical changes involved in the cooking of food.

In this unit, we will apply some basic principles of physics to three simple recipes. If possible, you should try out the recipes for yourself.

You will probably have covered the basic principles in your science or physics lessons. Here is a simple summary.

Part 1 — Some important principles

1 Heat transfer

Heat is transferred from one place to another in three ways:

(a) *Conduction* The flow of heat through a substance from places of higher temperature to places of lower temperature, without the substance itself moving. Conduction allows heat to travel to the centre of a potato when it is cooked (Figure 1).

Some substances conduct heat better than others. Metals are good conductors. Air is a poor conductor (a good insulator).

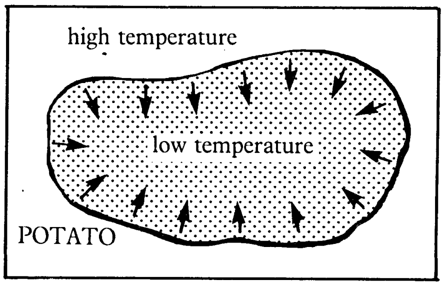


Figure 1 Conduction of heat to the centre of a potato

(b) *Convection* The transfer of heat by the *movement* of a liquid or a gas because of temperature differences in it.

Hot liquids or gases are less dense than cool ones. They therefore rise, which makes the hot mix with the cold. Convection allows heat to travel through water when it is heated in an electric kettle (Figure 2).

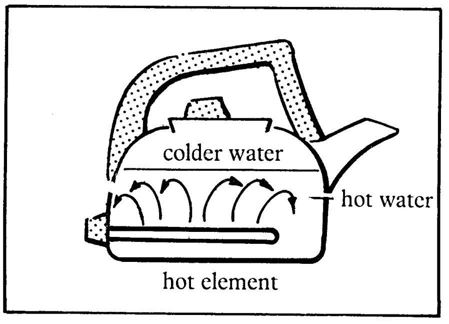


Figure 2 Convection in an electric kettle

(c) *Radiation* The transfer of heat as rays. These rays are infra-red rays, a form of electromagnetic radiation. They can pass through empty space.

Radiation allows heat to pass from a hot grill to a piece of toasting bread (Figure 3).

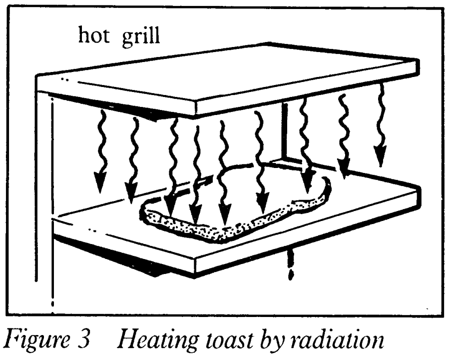


Figure 3 Heating toast by radiation

2 Surface area

Objects gain or lose heat through their surfaces. The larger the surface area, the faster heat can be gained or lost. For any object, the surface area can be increased by cutting it up into smaller pieces. This is why potatoes cook faster when cut into pieces (Figure 4).

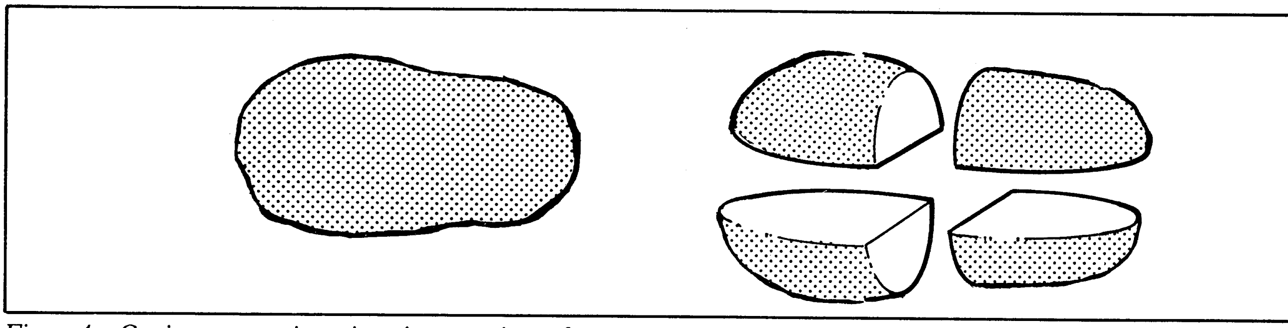


Figure 4 Cutting a potato into pieces increases its surface area

3 Expansion

All substances expand when they are heated. Gases expand much more than solids or liquids, for a given rise in temperature.

Part 2 — Boiling eggs

Recipe for soft-boiled eggs

Carefully lower the eggs into gently boiling water and cook them for four minutes (Figure 5).

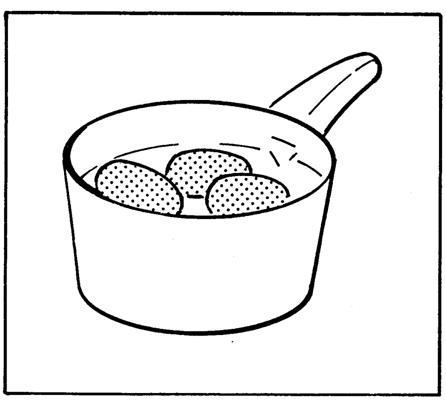


Figure 5 Boiling eggs

Questions

1 Describe
- *(a) how you like your 'perfect' boiled egg*
- *(b) what a four-minute boiled egg is like*

2 By which process, conduction, convection or radiation, does heat
- *(a) pass through the base of the saucepan*
- *(b) spread through the water*
- *(c) pass into the eggs?*

3 Why does heat flow into, not out of, the eggs?

4 Does heat reach the middle of an egg immediately cooking begins? Give a reason for your answer.

This recipe does not mention the size of the eggs. It also assumes that the eggs have been stored at room temperature.

5 Describe, giving reasons, what you would have to do to cope with
- *(a) different sizes of eggs*
- *(b) eggs which had been stored in a refrigerator.*

6 It takes longer to boil an egg at the top of a mountain than at sea level. Try to explain why.

Part 3 — Sponge cakes

Good food has a variety of colours, flavours and textures. Think how the texture of crusty bread or of crisp Yorkshire pudding contrasts with the soft inside.

Even a boiled egg has two contrasting textures: a firm 'white' but a soft, runny yolk.

Cooking a boiled egg is simple because

1 All eggs are of roughly the same shape and mass

2 The cooking temperature is fixed at the boiling point of water.

Usually there are more variables to control. Take sponge cakes as an example. This recipe can be used either for a sponge sandwich or for small cakes. Try it for yourself.

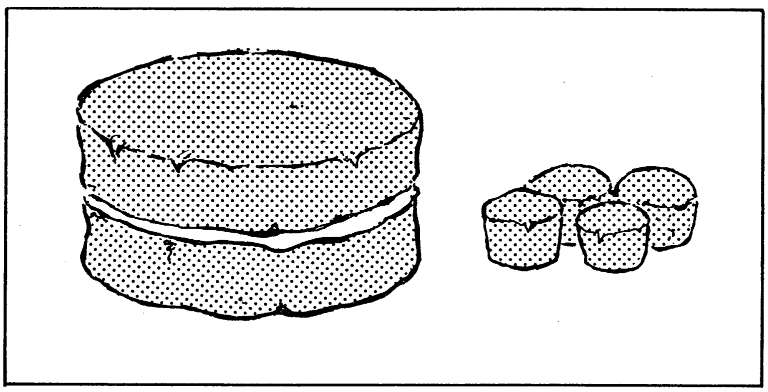


Figure 6 Sponge cakes

Recipe for sponge sandwich cake or small cakes

0.1 kg margarine
0.1 kg caster sugar
0.1 kg self-raising flour
(0.1 kg is about 4 ounces)
2 eggs

1 Beat the margarine and sugar together with an electric mixer or a wooden spoon until the mixture is light and fluffy.
2 Gently beat the eggs together in a basin.
3 Add the eggs a little at a time to the margarine/sugar mixture.
4 Gently stir in the flour. Mix thoroughly.
5 Bake in greased tins according to Table 1.

Table 1 Baking temperatures and times for sponge cakes

Cake	*Baked in*	*Temperature/ °C*	*Time/min*
sandwich cake	2 sandwich tins (about 180mm diameter)	180 (350°F, gas mark 4)	20
small cakes	10 small tins or paper cases	190 (375°F, gas mark 5)	15

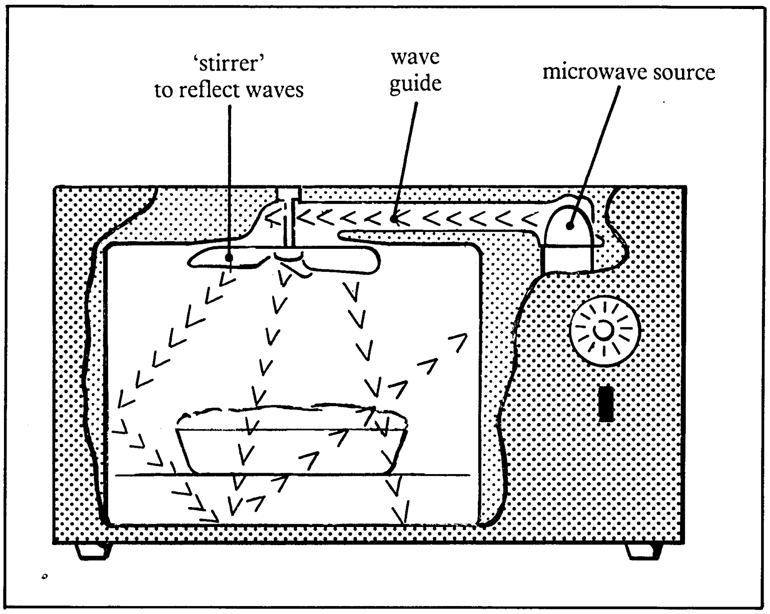


Figure 7 A microwave oven

Sponge cakes, and many other foods, can be cooked very quickly in a microwave oven (Figure 7). These ovens heat food using microwave radiation. Here are some properties of microwaves.

- They are a form of electromagnetic radiation. They travel at the speed of light and have a wavelength of 122 mm.
- They are absorbed by water. Water gets hot when it absorbs microwaves, because the microwaves make the water molecules vibrate. This makes microwaves useful for heating food, because all food contains water.
- They pass through air, glass and plastic without causing any heating. They are reflected by metal.
- They can penetrate food to a depth of about 50 mm.

Questions

7 How does heat travel from
(a) the oven heater to the cake
(b) the outside of the cake to the inside?

8 In which size of cake (sandwich or small) will heat reach the centre more quickly?

9 Explain why the spongy texture makes this type of cake a very poor conductor of heat.

10 Why do sponge cakes
(a) rise in the oven?
(b) flop if they are taken out too soon?

11 The larger sponge cake is baked in a cooler oven than the smaller cakes. This is because when a large cake is baked in a hot oven, it gets burnt on the outside before it is completely cooked in the middle. Why does this happen?

Question

12 Explain the following about microwave cookery:
(a) Microwave ovens cook food much more quickly than ordinary ovens
(b) Food baked in microwave ovens is not brown on the outside
(c) Food to be baked in microwave ovens must not be put in metal tins
(d) Plastic containers can be used in microwave ovens, but not in ordinary ovens
(e) To bake a good sponge cake in a microwave oven, you need to add a little water to the cake mixture.

Part 4 — Baked Alaska

Baked Alaska is a hot ice cream dessert. It is made of ice cream, sponge cake and soft meringue (Figure 8).It is baked in a hot oven until the peaks of the meringue are golden.

But why doesn't the ice cream melt?

Try it yourself and find out. The recipe given below is very easy.

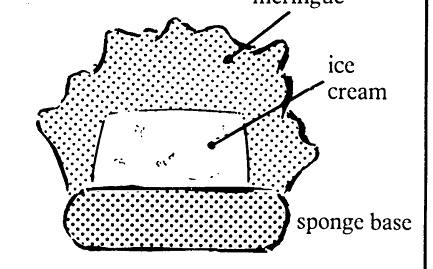


Figure 8 Cross-section through a Baked Alaska

Recipe for Baked Alaska

sponge cake, 180 mm diameter approximately (buy one or use the recipe in Part 3 to make your own)
family size block of vanilla ice cream
raspberry sauce or jam
3-4 egg whites
0.1 kg caster sugar (about 4 ounces)

1 Preheat the oven to 230°C (450°F, gas mark 8).
2 Place the sponge cake on a flat heatproof dish.
3 Spread the raspberry sauce or jam on the top of the sponge.
4 Make the meringue by whisking the egg whites until they are stiff (use an electric mixer if you have one). Add the sugar and whisk again.
5 Place the ice cream on the sponge cake, and spread the meringue mixture carefully all over it. Make sure that there are no gaps.
6 Bake in the hot oven for three minutes until the outside of the meringue just begins to turn golden brown.
7 Serve immediately.

Questions

13 Both meringue and sponge cake are good insulators. Explain why.

14 Explain why the ice cream does not melt.

15 The secret of success is to cook this dish in a very hot oven. Explain why.

16 Why is it not possible to prepare this dish in small individual portions?