SCIENCE & TECHNOLOGY IN SOCIETY

9

ase

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, there is a *General Guide for Teachers* which gives 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 *General Guide for Teachers.*

The names of contributors to this particular book are given on the inside of the back cover.

First published 1988 by The Association for Science Education

Designed by P & PS (Cambridge) Ltd.

SATIS 9

List of units in this book

EVALUATION OF SATIS UNITS

Users of the units in this book are invited to evaluate them by completing the questionnaire on the next page. Such feedback is of great value in helping to revise and improve the units and in determining future policy.

The Association for Science Education
College Lane
Hatfield
Herts AL10 9AA

ISBN 0 86357 046 1

List of units in the SATIS series

Evaluation of SATIS units

Your opinions as an experienced teacher will help to revise and improve the SATIS units in this book and to influence the style of future units.

Please
- Complete a response table (overleaf) for any unit you have used. If you need more response tables, please make photocopies.
- Return the completed sheet(s) to:

  SATIS Evaluation, ASE, College Lane, Hatfield, Herts AL10 9AA

Information about your school

Name of SATIS contact person: ....

Role: ....

Name of school: ....

Address: ....

....

Type of school *(Please circle)*:

Comprehensive   Grammar   Secondary Modern   Independent   Other

Boys only   Girls only   Mixed

Age range: ....   Total school roll: ....

Your opinions about the SATIS units in this book

The aspects for comment are listed below and we have provided response tables on the other side of this sheet. For each unit:

Please
- Complete the headings
- Tick the box which most closely reflects your opinion about each aspect of the unit you have taught
- If you have 'no opinion', or do not wish to give one, please tick the box on the extreme right.

Aspects for comment

(a) Relevance for GCSE courses (Is the unit relevant to your course?)
(b) Students' apparent interest (Did the unit stimulate interest in your students?)
(c) Language level (Is the unit written at a suitable level for your students?)
(d) Concept level (Were the conceptual demands appropriate?)
(e) Suggested amount of time (Was there enough time to complete the unit?)
(f) Recommended teaching/learning method (Was this appropriate for the unit?)
(g) Presentation (layout, diagrams, photos, print size) (Was all this suitable?)
(h) Teachers' notes (blue sheets) (Did you find these useful?)
(i) The teaching sequence in the unit (Was the unit organised suitably?)
(j) Requirements for students' response (Did the unit require suitable activities and feedback from students?)

I intend to use the following units again without revision. (Please quote unit number only.)
I intend to use the following units again, with revision.
I do not intend using the following units again.

SATIS unit number ....

Years and abilities used with ....

(a) Relevance for GCSE	Very relevant	Relevant	Little relevance	Not relevant	No opinion
(b) Students' apparent interest	Very interested	Interested	Little interest	Bored	No opinion
(c) Language level	Very suitable	Suitable	Quite difficult	Very difficult	No opinion
(d) Concept level	Very appropriate	Appropriate	Not appropriate	Completely in-appropriate	No opinion
(e) Suggested amount of time	Very satisfactory	Satisfactory	Difficult to meet	Badly estimated	No opinion
(f) Recom-mended teaching/ learning method	Very appropriate	Appropriate	Needs improving	Not at all appropriate	No opinion
(g) Presentation (Layout, dia-grams, photos, print size, etc.)	Excellent	Good	Needs improving	Poor	No opinion
(h) Teachers' notes (the blue sheets)	Very useful	Useful	Need improving	Of little use	No opinion
(i) The teaching sequence in the unit	Very suitable	Suitable	Needs some reorganising	Needs much reorganising	No opinion
(j) Requirements for students' response	Very suitable	Suitable	Need improving	Unsuitable	No opinion

Further comment:

SATIS unit number ....

Years and abilities used with ....

(a) Relevance for GCSE	Very relevant	Relevant	Little relevance	Not relevant	No opinion
(b) Students' apparent interest	Very interested	Interested	Little interest	Bored	No opinion
(c) Language level	Very suitable	Suitable	Quite difficult	Very difficult	No opinion
(d) Concept level	Very appropriate	Appropriate	Not appropriate	Completely in-appropriate	No opinion
(e) Suggested amount of time	Very satisfactory	Satisfactory	Difficult to meet	Badly estimated	No opinion
(f) Recom-mended teaching/ learning method	Very appropriate	Appropriate	Needs improving	Not at all appropriate	No opinion
(g) Presentation (Layout, dia-grams, photos, print size, etc.)	Excellent	Good	Needs improving	Poor	No opinion
(h) Teachers' notes (the blue sheets)	Very useful	Useful	Need improving	Of little use	No opinion
(i) The teaching sequence in the unit	Very suitable	Suitable	Needs some reorganising	Needs much reorganising	No opinion
(j) Requirements for students' response	Very suitable	Suitable	Need improving	Unsuitable	No opinion

Further comment:

SATIS unit number ....

Years and abilities used with ....

(a) Relevance for GCSE	Very relevant	Relevant	Little relevance	Not relevant	No opinion
(b) Students' apparent interest	Very interested	Interested	Little interest	Bored	No opinion
(c) Language level	Very suitable	Suitable	Quite difficult	Very difficult	No opinion
(d) Concept level	Very appropriate	Appropriate	Not appropriate	Completely in-appropriate	No opinion
(e) Suggested amount of time	Very satisfactory	Satisfactory	Difficult to meet	Badly estimated	No opinion
(f) Recom-mended teaching/ learning method	Very appropriate	Appropriate	Needs improving	Not at all appropriate	No opinion
(g) Presentation (Layout, dia-grams, photos, print size, etc.)	Excellent	Good	Needs improving	Poor	No opinion
(h) Teachers' notes (the blue sheets)	Very useful	Useful	Need improving	Of little use	No opinion
(i) The teaching sequence in the unit	Very suitable	Suitable	Needs some reorganising	Needs much reorganising	No opinion
(j) Requirements for students' response	Very suitable	Suitable	Need improving	Unsuitable	No opinion

Further comment:

SATIS unit number ....

Years and abilities used with ....

(a) Relevance for GCSE	Very relevant	Relevant	Little relevance	Not relevant	No opinion
(b) Students' apparent interest	Very interested	Interested	Little interest	Bored	No opinion
(c) Language level	Very suitable	Suitable	Quite difficult	Very difficult	No opinion
(d) Concept level	Very appropriate	Appropriate	Not appropriate	Completely in-appropriate	No opinion
(e) Suggested amount of time	Very satisfactory	Satisfactory	Difficult to meet	Badly estimated	No opinion
(f) Recom-mended teaching/ learning method	Very appropriate	Appropriate	Needs improving	Not at all appropriate	No opinion
(g) Presentation (Layout, dia-grams, photos, print size, etc.)	Excellent	Good	Needs improving	Poor	No opinion
(h) Teachers' notes (the blue sheets)	Very useful	Useful	Need improving	Of little use	No opinion
(i) The teaching sequence in the unit	Very suitable	Suitable	Needs some reorganising	Needs much reorganising	No opinion
(j) Requirements for students' response	Very suitable	Suitable	Need improving	Unsuitable	No opinion

Further comment:

The Chinese Cancer Detectives

Contents: Reading, questions, role-play and practical work related to the story of the identification of the cause of oesophageal cancer in Lin Xian, China.

Time: Homework plus 2 to 3 periods.

Intended use: GCSE Biology and Science.

Aims:

- To complement work on cell division, nutrition, and food preservation
- To describe in outline the nature and variety of cancers
- To develop an awareness of the research needed to identify the causes of a disease such as cancer
- To provide an opportunity to evaluate information
- To provide an opportunity to practise a range of communication skills.

Requirements: Parts 1 and 2 of the students' worksheets No.901 will be needed for homework. Part 3 will then be required for follow-up in class. A variety of materials for making leaflets and posters may be necessary in Part 3. Some students may wish to use a tape recorder.

Author: Anne Charlton

Suggested use of the unit

The unit is in three parts. Parts 1 and 2 could be set for homework so that the students are familiar with the information before they start Part 3 which will need a double period in school. At the end, each group might be asked to put across their 'message' to the rest of the class.

Possible recommendations to the people of Lin Xian (pronounced Lin Zyan) based on the research findings might be:

- To drink only purified water low in nitrites
- To eat only fresh vegetables, not pickled mouldy ones
- To add molybdenum to the seeds when they are sown
- Not to eat mouldy food
- To build waterproof drying areas for grain to stop it going mouldy when stored.

Perhaps the most important message for the students in this unit is that there are hundreds of different types of cancer, all with different causes and different behaviour. There can be more than one cause for cancer in a particular organ. *It is important to emphasize that the one described here is exceptional and a very local one.* However, the Lin Xian example illustrates well both the complex process of tracking down the various elements involved in causing the cancer, and the problems involved in getting people to change their time-honoured procedures in order to prevent one particular cancer. We have the same problem in this country where cigarette smoking has been indentified as the main cause of lung cancer. Even so, some people are unwilling to give up smoking.

Background information

Much of the research into the causes and prevention of cancers investigates the distribution of particular types of cancer among specific groups of people.

There is a very wide variation between the most frequent cancers from country to country. For example, in many westernised countries, including Britain, USA, Canada, Australia, New Zealand and Western Europe, lung cancer is the most common cancer in men and breast cancer is the most frequent for women. However, in Japan, stomach cancer is the most frequent in both sexes. In South America, cancer of the uterine cervix is the most frequent cancer in women, while in other parts of the world, including Egypt, and much of Africa, liver cancer is most frequent.

When a 'high risk' group is identified, researchers attempt to identify the factor in the life style of the members of the group which might be carcinogenic. When a possible factor is strongly suspected it is put to the test of laboratory research.

There is, however, a very important problem in the identification of the carcinogen because the process of carcinogenesis is almost certainly caused by many factors and often includes a long latent period between contact with the carcinogen and the appearance of a recognisable cancer.

The process of carcinogenesis is not well understood. In the case of the cancer sufferers of Lin Xian it seems odd that a product of digestion should cause cancer of the gullet. However, it quite often happens that the effect of a carcinogen appears at a different site from that of contact. Tobacco smoke can cause cancer of the pancreas and liver; bracken (when eaten by humans as it is in Japan) causes cancer of the gullet; aflatoxins produced by the fungus *Aspergillus flavus* cause liver cancer. Presumably the products which act as carcinogens are absorbed and carried in the blood as are other products of digestion. Certain types of cell are sensitive to particular carcinogens, so presumably if they enter these cells, and other necessary conditions are also fulfilled, a cancer will be initiated.

Other resources

1. Edward Goldwyn's article, 'The Chinese cancer detectives' (*The Listener,* 21 February 1980, pp.236-8) tells the story of Lin Xian.
2. A wall chart and accompanying leaflet on the distribution of the most frequent cancers throughout the world are available on sale from the Cancer Research Campaign, 2 Carlton House Terrace, London SW1Y 5AR. (Tel. 01-930 8972.)
3. There are several very good basic books about cancer and its causes in general. Two are: *Cancer: the Facts* by Sir Ronald Bodley Scott (Oxford University Press, new edn, 1981); *The Causes of Cancer* by R. Doll and R. Peto (Oxford University Press, 1982).

Acknowledgements Figure 1 supplied by the Cancer Research Campaign Laboratories, Department of Medical Oncology, Charing Cross Hospital; Figure 2 supplied by the Department of Medical Illustration, St Bartholomew's Hospital.

THE CHINESE CANCER DETECTIVES

This unit tells the story of a group of scientists who tracked down the cause of one kind of cancer. The scientists studied the people of Lin Xian in China where the cancer was unusually common. They worked like detectives, collecting clues, until they were able to work out the likely cause of the disease.

The unit is in three parts:

Part 1 What is cancer?
Part 2 The story of Lin Xian
Part 3 How can we save lives?

Part 1 What is cancer?

Cells in our bodies divide all through our lives. They do this for two reasons:

- so that we can grow, and
- to replace cells which are worn out, or lost in other ways.

Normally cell division is under strict control. Just the right number of new cells are made.

Sometimes something causes a cell to begin to divide in an uncontrolled way. Fortunately this does not happen very often. When it does happen a group of unusual cells forms. These abnormal cells do not become muscle cells, or skin cells or blood cells. Instead they just keep dividing more rapidly than normal cells. A lump of cells forms which is called a tumour.

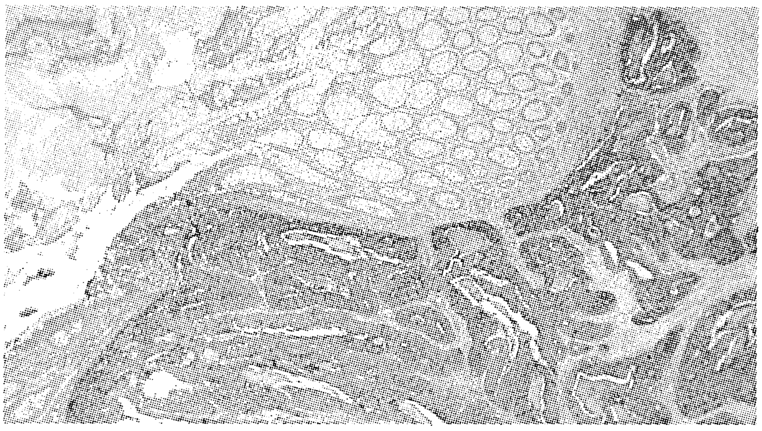


Figure 1 Normal and cancerous cells under the microscope (magnified 40 times). The cells are from a human bowel. The normal cells are the regularly shaped ones at the top. The cancer cells are the oddly shaped ones at the bottom.

Some tumours are **benign** tumours. Cells from these tumours do not spread between the surrounding normal cells.

Other tumours are **malignant** tumours, or cancers. Cells from malignant tumours can spread between surrounding cells and eventually reach blood vessels or lymph vessels. Small groups of cells may break off from the tumour and be carried by the blood, or lymph, to start secondary cancers in other parts of the body. This process is called **metastasis**.

Answer questions 1 to 3.

Questions

1 *Why do cells in our bodies divide throughout the whole of our lives?*
2 *Uncontrolled cell division produces unusual cells. How are the abnormal cells different from normal cells?*
3 *What is the main difference between a benign tumour and a malignant tumour?*

There are hundreds of different kinds of tissue in our body. Cell division happens in them. So there are many places where cell division can go wrong. This means that there are hundreds of kinds of cancer according to where the first tumour starts to grow. These cancers are all very different in their causes and effects, and need different treatments.

There must be some kind of 'trigger' to start a cell dividing in the wrong way. This trigger is called a **carcinogen**. The way in which a carcinogen has its effect may not be simple. Sometimes there may be a long gap between contact with the carcinogen and the start of the cancer. Also the carcinogen may not have an effect on its own.

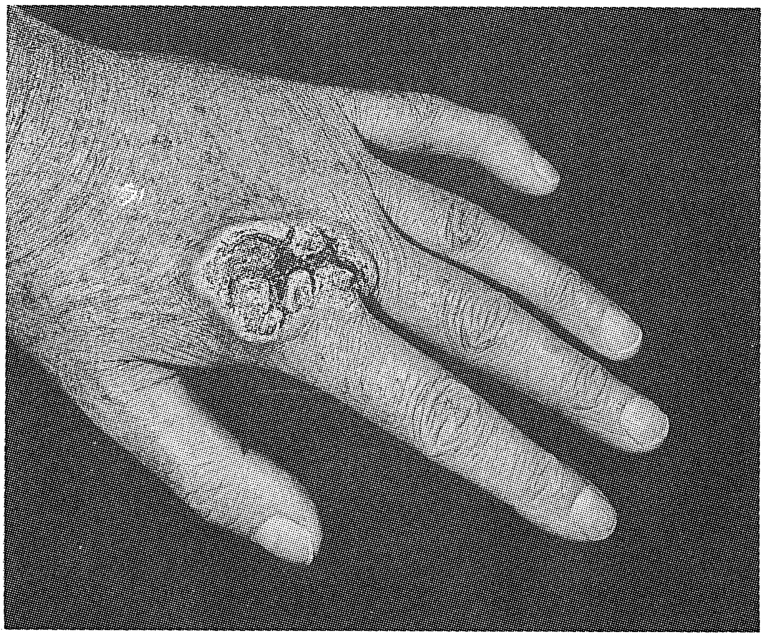


Figure 2 A skin cancer

Some groups of people seem more likely to develop particular types of cancer. Scientists try to discover what these people have in common in the hope of finding the carcinogen. Then it may be possible to reduce the risk of cancer by cutting down the exposure to the carcinogen.

Part 2 of this unit describes one type of cancer in a particular group of people. The causes of all cancers are complex and the same detailed research is needed for all of them.

Answer questions 4 to 6.

Questions

4 *Why is it so difficult to identify the causes of cancer?*

5 *What information can sometimes give researchers the first clue to the cause of some cancers?*

6 *Give an example of a substance which has been identified as a carcinogen and is now being removed, as far as possible, from our environment.*

Part 2 The Story of Lin Xian

Lin Xian is a remote valley in China. Cancer of the gullet (oesophagus) is about one hundred times more common among the people who live in this valley than in the surrounding areas of China. This seems to have been the case for many centuries.

Why? It needed a team of scientists to find out the reason. You will see why as you look at the evidence and the deductions.

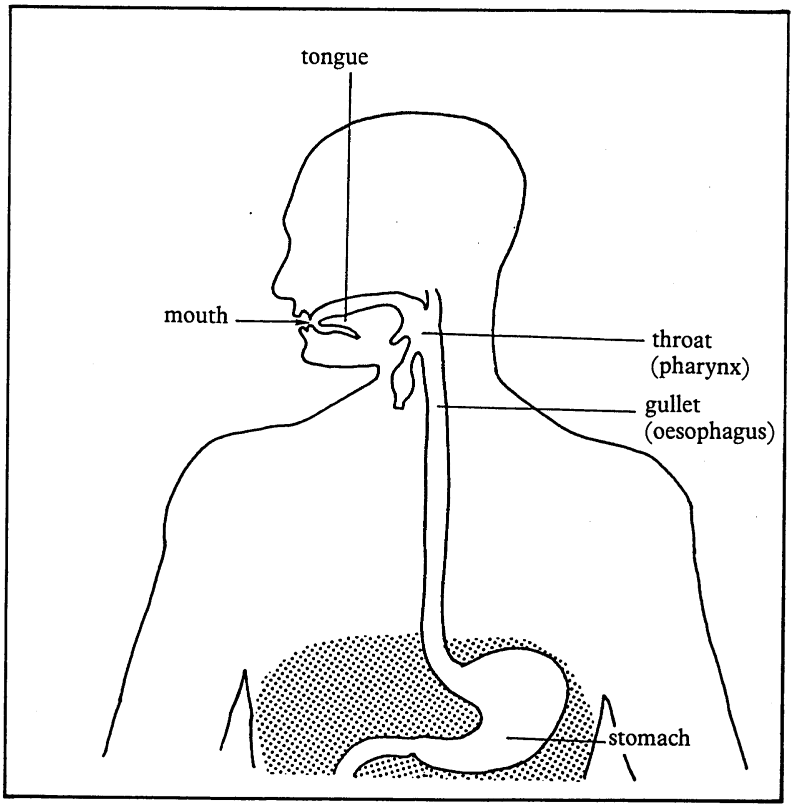


Figure 3

Evidence

- Analysis showed that the soil in the Lin Xian valley is short of the element molybdenum.
- The water supply in the valley was found to be high in chemicals called nitrites.
- The people of Lin Xian liked mouldy food. They ate mouldy bread, pickled cabbage rotted in water, and persimmon (a fruit) preserved in a crust of dried wheat husk.
- Wherever the people of Lin Xian valley had a high rate of cancer, so too did their chickens.
- The people in Lin Xian had a high level of nitrites in their bodies and a low level of vitamin C.

Deductions

The scientists used this evidence to find the cause of cancer. Here is part of their reasoning.

a The chickens probably got the cancer because they were fed on food scraps by the people of Lin Xian. So it was probably something in the food which caused the cancer.

b Plants which are short of molybdenum contain more nitrites than normal. They also contain little vitamin C.

c Nitrites in food can be turned into harmful chemicals called nitrosamines during digestion.

d Some of the moulds on the bread and cabbage in Lin Xian produced nitrosamines. They also produced amines which can combine with nitrites during digestion to make nitrosamines.

e Nitrosamines can cause cancer. It was probably nitrosamines causing the high rate of cancer of the gullet in the people of Lin Xian.

f Vitamin C helps to protect against the effects of nitrosamines.

Answer questions 7 to 11.

Questions

7 *What did the people of Lin Xian - and their chickens - have in common?*

8 *What two things are unusual about plants grown on soil which is short of molybdenum?*

9 *Which two chemicals were formed by the moulds on the bread, cabbage and fruit?*

10 *What chemical was there too much of in the water supply in Lin Xian? Does the evidence suggest that this chemical is harmful on its own?*

11 *What advice do you think should be given to the people of Lin Xian to help them reduce the risk of cancer of the gullet? Write down your recommendations in four or five short statements.*

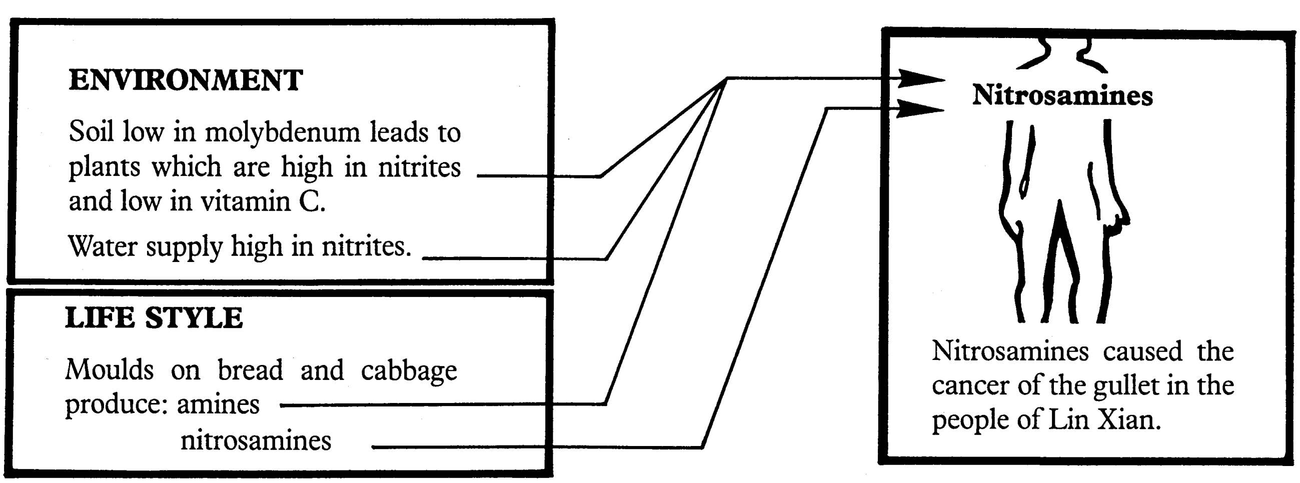


Figure 4

Part 3 How can we save lives?

In this role-playing exercise you will be working in groups of four. Each student in a group will take the part of one of the following characters: a doctor, a research worker, a social worker, a school teacher. Together you form a small group of village leaders. You have studied the results of the research into the causes of cancer of the gullet in Lin Xian. You are meeting to decide what should be done to help the people who live in the valley.

You have to decide two things to help people cut down the risk of cancer of the gullet:

A What advice should be given to the people based on the research results?

B How the message should be put across so that people change their life style and cut down the risk.

Each member of the group is asked to give a brief report on his or her recommendations. The group also has to produce some sample publicity material. You may decide to use posters, leaflets, slogans, radio or TV items, and so on.

Read the brief guidelines on your role below, before making your report.

Dr Ko You are the doctor who has had to treat so many people in Lin Xian for cancer of the gullet. You feel that the cancers are a tragic waste of life, particularly now that they can be prevented. You are aware of the difficulties of getting people to pay attention to health campaigns. You have met many patients who have ignored your advice about smoking and eating habits.

Ms/Mr Wong You are one of the researchers who helped to find the causes of cancer. You are very keen to see that the results of your work are fully understood by the people of the valley.

Mr/Ms Lo You are the social worker. Your job is to help to persuade the people to change their habits so as to help to prevent cancer. You know from past experience how difficult it can be to persuade people to change their ways. This is particularly true with older people.

Ms/Mr Chang You are a local school teacher. You want to get the message across to your young pupils so that they will be unlikely to get cancer. You already have a programme of health education in your school. You have to decide how to add this new message to your teaching. Past experience tells you that many children are influenced more by family and friends than by what they are told in school.

Acid Rain

Contents: A structured discussion about the problems of acid rain.

Time: 4 periods plus homework. This allows time for an audiovisual programme at the start. The total time needed will depend on the way in which the groups report on their conclusions.

Intended use: GCSE Biology, Chemistry and Science courses. Links with work on air pollution, fossil fuels, energy sources and acidity.

Aims:

- To complement and revise prior work on pollution, fuels, energy and acidity
- To outline the origins of acid rain and the problems associated with it
- To develop awareness of the complexity of the scientific, economic and environmental issues associated with pollution problems
- To encourage readiness to enter into discussion
- To provide opportunities to develop interpersonal and communication skills.

Requirements: Students' worksheets No. 902.

For each member of the class:

1 copy of General Briefing (sheets GB1 and 2)
1 copy of the Test (sheet T)

For each group of 5 students:

1 copy of each of the Expert's Briefings (sheets EB1, EB2, EB3 and EB4)
1 copy of the Chairperson's Briefing (sheet CB)

Some groups may need access to materials for producing a poster, OHP transparency or other means of explaining their chosen policy for dealing with acid rain. (See the final part of sheet CB.)

Author: Roland Jackson

This unit is best used after an audiovisual introduction. The SATIS Audiovisual production *Acid from the Air* might be used (see 'Other Resources').

The unit emphasizes the effects of acid rain on living things in lakes as well as on corrosion. There is little mention of the effect on trees because — at the time of writing — the experts disagree on the reasons for the death of trees.

The information in the briefings is presented in note form. Students have to put together the information to make a coherent statement. Encourage the groups to make positive suggestions and not just emphasize outrage and protest.

One of the problems in discussions of this subject concerns the definition of the term *acid rain.* Popularly it is used to encompass many different forms of air pollution which mostly have their origin in the combustion of fuels. The three most important are acid rain itself, gaseous sulphur dioxide and ozone. These types of pollution have to be distinguished because they differ in their origins, have different environmental effects and require different control measures.

Building decay is thought to be accelerated by high concentrations of sulphur dioxide in the air rather than by acid rain. High concentrations of sulphur dioxide used to occur near ground level in towns and cities where there were many local sources. Power stations contributed little to this problem. The solution was clean air legislation and the replacement of coal by natural gas and electricity for much domestic heating.

Cutting sulphur dioxide emissions from power stations is, however, appropriate in the case of long-range acid rain. Power stations produce two-thirds of the nation's output of sulphur dioxide.

Ozone may turn out to be important in the decline of forests. If so, the most probable effective action could be to reduce the emission of unburnt hydrocarbons from vehicles. The chemistry is complex: cutting the NO_x in exhausts might lead to *higher* levels of ozone pollution. Cutting down on oxides of nitrogen may reduce acid rain, though even this is not certain.

Procedure

1 Show an audiovisual programme to give students a picture of the problem.

2 Issue a copy of the General Briefing (sheets GB1 and 2) to each student and allow time for students to read it. This might be done for homework.

3 Get the students to do the test. This will take 10 to 15 minutes. Students might be allowed access to the General Briefing either while doing the test or when checking the answers.

4 Form the class into groups of five. Each group should have a Chairperson, chosen for his or her potential for leading a discussion.

5 Give the Chairpersons their briefing (sheet CB). Give Expert Briefings (sheets EB1, EB2, EB3 and EB4) to the other members of the group — a different sheet to each member. If the class does not divide neatly into groups of five, have some groups of six. Sheet EB1 is longer than the others and it may help if two students have studied it.

6 Allow time for the students to study their briefings.

7 Hand over the running of discussions to the Chairperson.

8 Encourage the groups to formulate a policy for dealing with acid rain. Finally each group should present a report on their conclusions in some appropriate form. Some groups may like to extend their discussion along the lines suggested by the following questions:

- Even the experts disagree about the causes and effects of acid rain. Why is it so difficult to understand?
- Why does it matter if no fish can live in rivers and lakes?
- Why should we care if pollution from British power stations is killing the fish in the lakes of other countries?
- How might our lives be affected if we decide to make a big effort to solve the acid rain problem?
- Some people think that much more research needs to be done before we can make a sensible plan for tackling the acid rain problem. What would you say to such people?
- What can each of us do to help solve the problem of acid rain?
- Which of the methods of dealing with the acid rain problem are likely to be politically acceptable? Which are likely to be unacceptable?

Other resources

Videos/films

These two videos/films present contrasting views.

Acid rain — who cares? available on free loan as a 29-minute VHS video or 16 mm film from the Swedish Embassy, 11 Montague Place, London W1H 2AL.

Acid Rain available on free loan on VHS/Beta or 16mm film from CEGB Film and Video Library, Viscom Limited, Parkhall Road Trading Estate, London SE21 8EL.

Tape/slide sequences

SATIS Audiovisual, *Acid from the Air* (20 slides with a commentary), available from ASE.

Acid rain — the silent crisis (AVP 079) from the International Centre for Conservation Education, Greenfield House, Guiting Power, Cheltenham, Glos. GL54 5TZ.

Printed materials

Suggested sources:

There are regular articles about acid rain in newspapers and magazines including the *New Scientist.*
Ecology Party, 36/8 Clapham Road, London SW9 0JQ
Friends of the Earth, 26-28 Underwood Street, London N1 7JQ
Greenpeace, 36 Graham Street, London N1
National Society for Clean Air, 136 North Street, Brighton BN1 1RG
Central Electricity Generating Board, 15 Newgate Street, London EC1A 7AU (Department of Information and Public Affairs).

Acknowledgements Figure 2 (General Briefing) from *Acidification — a Boundless Threat to our Environment* (Swedish Ministry of Agriculture), reproduced by permission of the National Environmental Protection Board, Sweden; Figure 1 (Expert's Briefing 2) adapted from *Chemistry in Action Copymasters* (University of York Science Education Group); Figure 1 (Expert's Briefing 3) reproduced by courtesy of The British Petroleum Company, p.l.c.; Figure 1 (Expert's Briefing 4) supplied by courtesy of Lennart Henrikson.

ACID RAIN

General Briefing

What should we do about acid rain?

This is a controversial topic. No one is yet sure how much harm is done by acid rain. There are different theories to explain the effects of acid rain. Scientists disagree about the theories. Politicians are not sure that it is worth while spending large sums of money to solve a problem which is not properly understood.

You may see a film or be shown a tape-slide programme to give you a picture of the problems. You will study the information in this General Briefing and answer some questions in a short test. This will lead to a group discussion about possible ways of making rain less acid.

Where does acid rain come from?

- The pH of unpolluted rain is naturally about 5.0 because of dissolved gases including carbon dioxide. The pH of acid rain is lower than this, in the range 2 to 5.
- Coal and oil contain sulphur. When these fuels are burned, the sulphur turns to sulphur dioxide. Sulphur dioxide reacts in the air and in clouds to form sulphuric acid. Sulphuric acid makes rainwater acid.
- Some important metal ores are sulphides, such as copper and lead sulphides. Sulphur dioxide is formed when the metals are extracted from these ores.
- Some sulphur dioxide enters the air naturally from volcanoes and the decay of dead plants. But in Europe about 90 per cent of sulphur dioxide in the air comes from artificial sources.

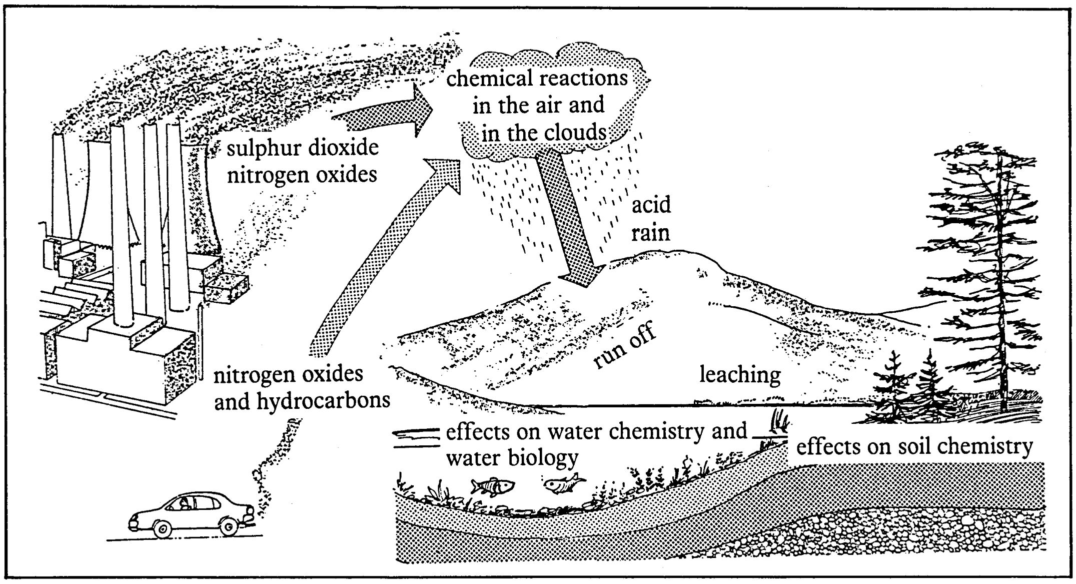


Figure 1

- Some sulphur dioxide enters the air naturally from volcanoes and the decay of dead plants. But in Europe about 90 per cent of sulphur dioxide in the air comes from artificial sources.
- The amount of sulphur dioxide given off in the UK fell by 37 per cent between 1970 and 1984 but the UK is still the largest producer of sulphur dioxide in Western Europe.
- About a third of the sulphur dioxide given off in Britain is carried by the westerly winds to Scandinavia and other parts of Europe. The rest lands in Britain or on the sea.
- Burning fuels also produce oxides of nitrogen. Oxides of nitrogen help cause acid rain. Motor vehicles are the major producer of oxides of nitrogen. Power stations also produce a lot.

Production of sulphur dioxide in Western Europe in 1982 (million tonnes)

Britain	4.2
West Germany	3.5
Italy	3.1
France	2.9
Spain	2.0

What are the possible effects of acid rain?

- Lakes in Scotland are affected by acid rain. Some are so acid that fish are dying.
- Living things may die if the pH in a lake falls below 5.
- 4000 Swedish lakes have no life in them. 16 000 Swedish lakes have little life.
- Norwegian stocks of arctic salmon are almost extinct. Over half the brown trout in Norway have died.
- Acid rain speeds up the corrosion of metals.
- Water supplies in parts of Scandinavia are now acid enough to corrode metals. They become contaminated with dissolved metals such as copper, zinc and cadmium. This makes the water taste foul and may be harmful to health.
- Many trees in Europe are dying. Some scientists say that this is due to acid rain. Other experts disagree and say that the damage is done by drought, disease or pests. Others think that different types of air pollution may be killing the trees.

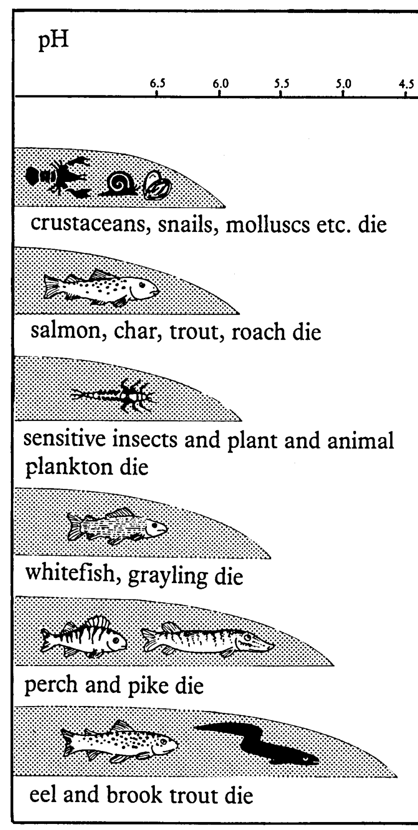


Figure 2

A test on acid rain

1 What are the natural sources of sulphur dioxide?

2 What are the artificial sources of sulphur dioxide?

3 Are the main sources of sulphur dioxide in Europe natural or artificial?

4 Why does sulphur dioxide make rainwater acid?

5 Which country in Western Europe produces most sulphur dioxide?

6 (a) Which gases, other than sulphur dioxide, help cause acid rain?
(b) Where do these gases come from?

7 Why is the acid rain in parts of Europe affected by what happens in other countries?

8 How does acid rain affect living things in lakes?

9 How does acid rain affect things made from steel?

10 Why is it hard to decide whether acid rain damages trees?

Expert's Briefing 1

Can we make rain less acid by cleaning up power stations?

You will shortly be taking part in a group discussion about acid rain. You will be trying to decide what you think should be done to cut down the problems caused by acid rain.

After you have read this briefing, the Chairperson of your group will be asking questions. You are the only one in your group who has read this sheet so you will be the expert on cleaning up air pollution from power stations.

When you, and the others in your group, have answered the questions you will try to decide what should be done about acid rain. You will try to think of constructive ways to solve the problem. As a group you will then prepare a short speech, or a leaflet or a poster to tell the rest of the class what you think should be done.

Information

- Coal and oil contain sulphur. When these fuels are burned the sulphur turns to sulphur dioxide. Sulphur dioxide reacts with air, other pollutants and water to form sulphuric acid. Sulphuric acid makes rainwater acid.
- Power stations release about two-thirds of the sulphur dioxide given off into the air in Britain. Most of the rest comes from industry.
- Sulphur can be removed from oil before it is burned. It is more difficult to remove the sulphur from coal.
- A process called 'flue-gas desulphurization' can remove the sulphur dioxide from the waste gases from power stations. Limestone is used to neutralize the sulphur dioxide.
- Fitting a flue-gas desulphurization plant would cost about £200 million pounds for a big power station. It would also cost about £30 million a year to run.
- Cutting down sulphur dioxide from all power stations could add about 10 per cent to electricity prices.
- The process for removing sulphur dioxide from power station flue gases uses limestone and produces calcium sulphate in a form which can be used to make plaster board for the building industry.
- Burning fuels in power stations produces oxides of nitrogen. Oxides of nitrogen help cause acid rain.
- Power stations release into the air about 40 per cent of the nitrogen dioxide emitted in Britain. Most of the rest comes from motor vehicles.
- The Central Electricity Generating Board are experimenting with new burners in power stations. The burners cut the production of oxides of nitrogen by a third. The cost of converting twelve power stations to the new burners was estimated to be £170 million in 1987. All large power stations will have new burners fitted during the next ten years.

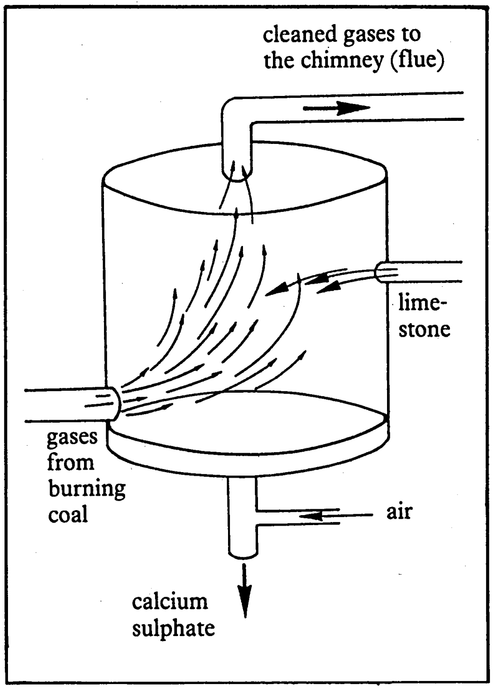


Figure 1 A simplified diagram to show how flue-gas desulphurization works

Expert's Briefing 2

Can we make rain less acid by cutting down pollution from motor vehicles?

You will shortly be taking part in a group discussion about acid rain. You will be trying to decide what you think should be done to cut down the problems caused by acid rain.

After you have read this briefing, the Chairperson of your group will be asking questions. You are the only one in your group who has read this sheet so you will be the expert on cutting down air pollution from motor vehicles.

When you, and the others in your group, have answered the questions you will try to decide what should be done about acid rain. You will try to think of constructive ways to solve the problem. As a group you will then prepare a short speech, or a leaflet or a poster to tell the rest of the class what you think should be done.

Information

- Burning fuels in vehicle engines produces oxides of nitrogen. Oxides of nitrogen help cause acid rain.
- Motor vehicles release into the air about 40 per cent of the oxides of nitrogen given off in Britain.
- Lower speed limits would help reduce the amount of oxides of nitrogen in vehicle exhausts. The percentage of nitrogen oxides in car exhausts falls from 0.11 per cent at 70 mph to 0.03 per cent at 30 mph.
- 'Lean-burn' engines have been designed which cut down the levels of nitrogen oxides in the exhaust to a quarter. These engines add about £30 to the cost of the car.
- Catalytic convertors can be fitted to cars. The catalysts cut down the amount of nitrogen oxides in the exhaust gases. Lead compounds stop the catalysts working.
- Cars with convertors have to run on lead-free petrol which costs more than ordinary petrol.
- A catalytic convertor costs about £500. It has to be replaced after the car has travelled 50 000 miles.

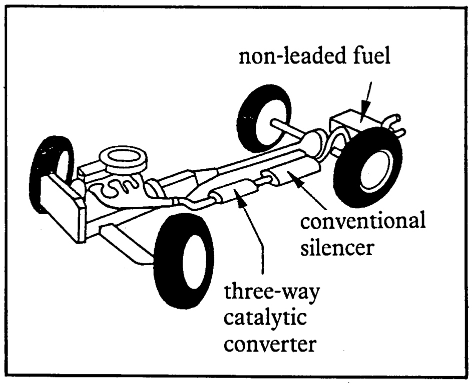


Figure 1

Expert's Briefing 3

Can we make rain less acid by cutting down on our use of fossil fuels?

You will shortly be taking part in a group discussion about acid rain. You will be trying to decide what you think should be done to cut down the problems caused by acid rain.

After you have read this briefing, the Chairperson of your group will be asking questions. You are the only one in your group who has read this sheet so you will be the expert on reducing acid rain by using less fuel.

When you, and the others in your group, have answered the questions you will try to decide what should be done about acid rain. You will try to think of constructive ways to solve the problem. As a group you will then prepare a short speech, or a leaflet or a poster to tell the rest of the class what you think should be done.

Information

- Coal and oil contain sulphur. When these fuels are burned the sulphur turns to sulphur dioxide. Sulphur dioxide reacts with air, other pollutants and water to form sulphuric acid. Sulphuric acid makes rainwater acid.
- Burning fuels in power stations and motor vehicles produces oxides of nitrogen. Oxides of nitrogen may help cause acid rain.
- We can cut down air pollution by using less energy. Saving energy means less fuel needs to be burned. Less coal will be burnt in power stations if we use less electricity .
- Nuclear power stations do not burn coal or other fuels so they do not emit oxides of nitrogen and sulphur.
- Developing wind power, solar power and hydroelectric power and other renewable sources of energy will produce electricity without adding to the acid rain problem.
- There would be fewer vehicles on the roads if more people used public transport.
- There would be fewer vehicles on the roads if more goods were transported by rail.

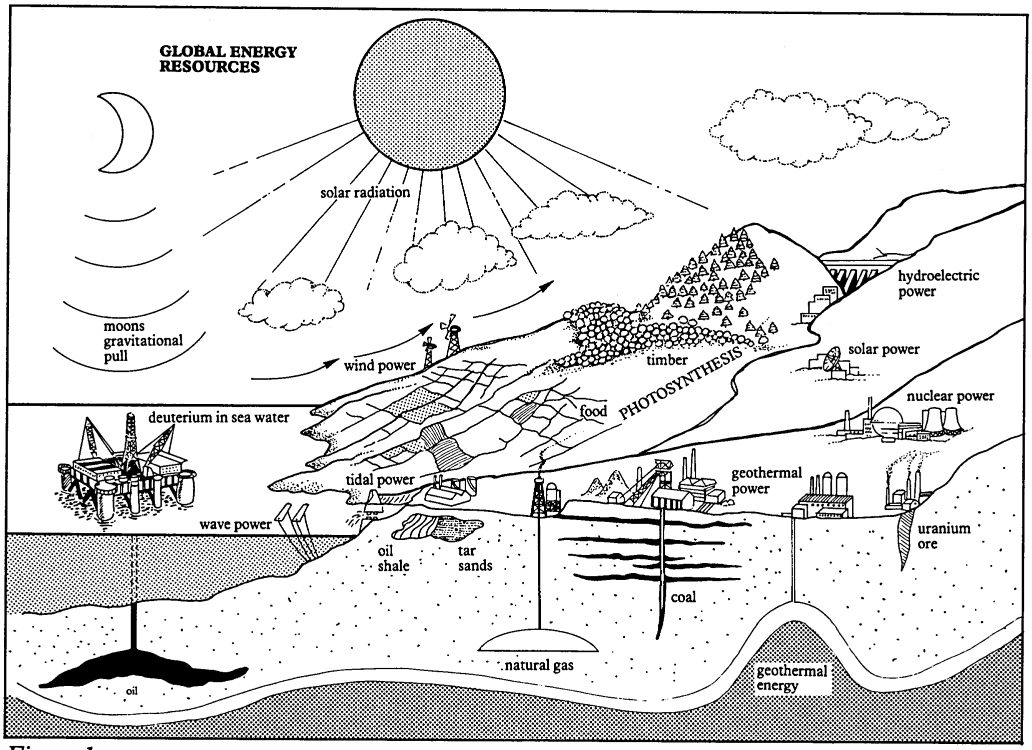


Figure 1

Expert's Briefing 4

Can we solve the acid rain problem by neutralizing the acids?

You will shortly be taking part in a group discussion about acid rain. You will be trying to decide what you think should be done to cut down the problems caused by acid rain.

After you have read this briefing, the Chairperson of your group will be asking questions. You are the only one in your group who has read this sheet so you will be the expert on solving the problem by neutralizing the acids. When you, and the others in your group, have answered the questions you will try to decide what should be done about acid rain. You will try to think of constructive ways to solve the problem. As a group you will then prepare a short speech, or a leaflet or a poster to tell the rest of the class what you think should be done.

Information

- Limestone is calcium carbonate. Calcium carbonate does not dissolve in pure water but it neutralizes acids.
- Limestone can be converted to calcium hydroxide - slaked lime.
- Powdered lime can be spread on the soil to neutralize acidity. Farmers have used lime to control the pH of the soil for centuries.
- Adding limestone to lakes neutralizes the acidity.
- Some experts believe that the cheapest way to reduce the acidity of lakes is to dose them with limestone. Liming will cost less than changing power stations to cut down the sulphur dioxide they give off. The cost of liming lakes in Sweden is around £25 million per year.
- Liming has to be repeated regularly because lakes soon become acid again if liming stops.

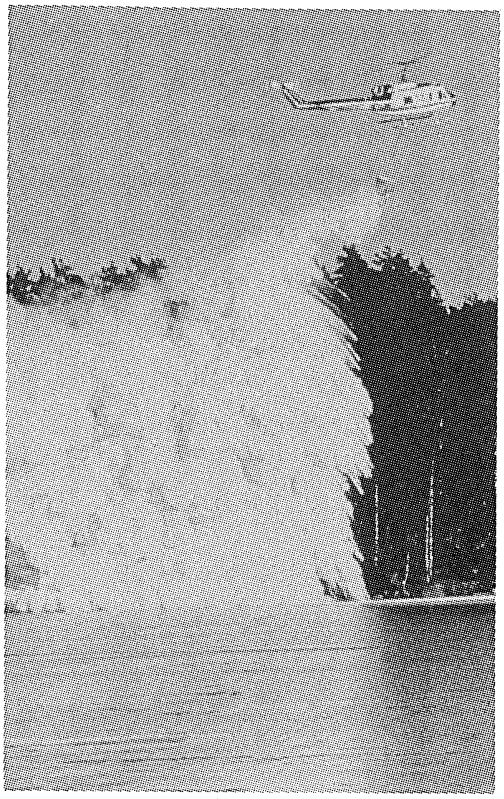


Figure 1 Spreading lime on a lake from the air

Chairperson's Briefing

You are the chairperson of a group of students. It is your job to ask questions and chair a discussion about acid rain. The point of the discussion is to examine possible ways of solving the problems caused by acid rain.

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 and they may also have watched a video or seen some slides. Each member (except you) will also have read an Expert's Briefing. The subjects of the expert briefings are listed in the box (right).

Begin by asking some questions about solving the problems of acid rain.

Subjects of Expert Briefings

1 Can we make rain less acid by cleaning up power stations?

2 Can we make rain less acid by cutting down pollution from motor vehicles?

3 Can we make rain less acid by cutting down on our use of fossil fuels?

4 Can we solve the acid rain problem by neutralizing the acids?

Suggested questions

1 What is acid rain?

2 How is acid rain formed?

3 How can air pollution from power stations be cut down?

4 What are the problems involved in dealing with air pollution from power stations?

5 They say we could cut down on air pollution by using other methods for generating electricity. Why?

6 How can air pollution from motor vehicles be cut down?

7 What are the problems involved in dealing with pollution from motor vehicles?

8 Are there any ways of reducing the acid rain problem which do not involve expensive changes to power stations and motor vehicles?

9 They say we could cut down acid rain by finding ways of burning less fuel. What are the problems involved in doing this?

10 They say we could deal with the problem by neutralizing the acids. How?

11 What are the problems involved in neutralizing the acids?

Group report

When your group has answered the questions try to get them to decide what should be done to solve the problem of acid rain. Encourage the group to come up with constructive ideas. Organise the group to prepare a short speech, or a leaflet, or a poster, to tell the rest of the class what you all think should be done.

What are the Sounds of Music?

Contents: Reading and questions about sound and music, together with suggested teacher demonstrations and class investigations.

Time: 2 to 4 periods for demonstrations and discussion followed by reading and questions for homework. Parts 1 to 3 of the unit can be used as a reading and comprehension exercise. Part 4 can be omitted if time is short.

Intended use: GCSE Physics and Science. Links with work on sound, wave motion and music.

Aims:

- To consolidate work on wave motion and sound. To exemplify the concepts of waveform, amplitude, frequency and displacement. To provide simple waveforms for interpretation
- To provide a simple understanding of the factors affecting the pitch, loudness and quality of musical notes from wind and stringed instruments
- To provide an elementary explanation of electronic sound synthesisers (pitch, harmonics, vibrato, waveform and envelope)
- To provide opportunities to apply physics concepts to interpret information
- To provide opportunities for planning and carrying out investigations.

Requirements: Students' worksheets No.903.

Apparatus for demonstrations: see the diagrams below.

Apparatus for investigations in Part 4: microphone, oscilloscope, a selection of musical instruments and tuning forks (if these are not available, different waveforms can be produced by singing and whistling), 3.5m length of hose-pipe, brass instrument mouthpiece, funnel, 2 or more signal generators and loudspeakers. Leads for connecting together the electrical equipment.

A VELA (program 010) and a synthesizer can be used for extension work.

Author: Anabel Curry

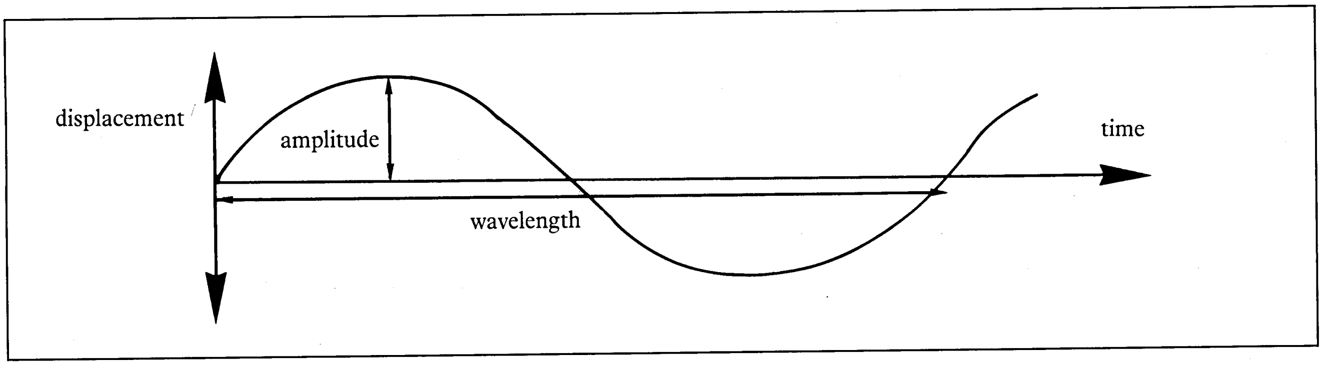
This unit is in four parts:

Part 1 Music or noise ?
Part 2 Strings and wind
Part 3 Synthesizers
Part 4 Investigations.

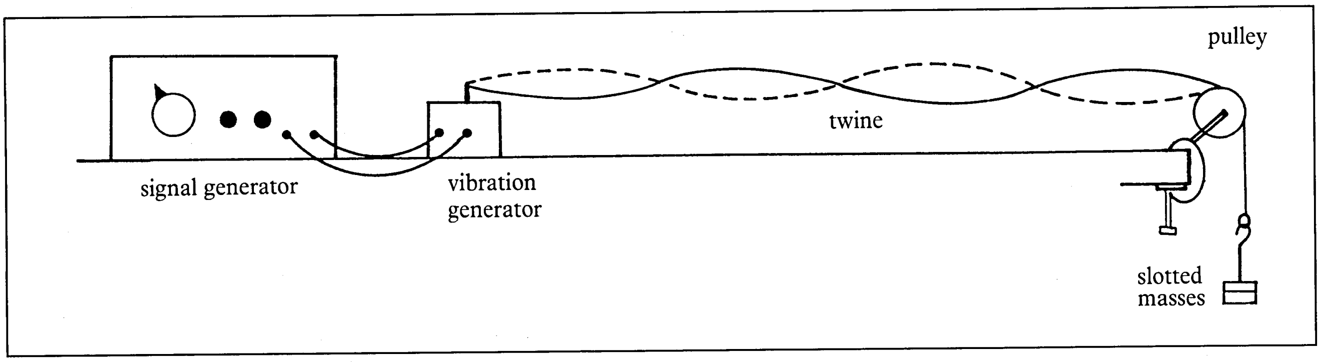
Part 1 Music or Noise?

The unit hints at the distinction between subjective noise, which is anything someone does not want to hear, and objective noise, such as the hissing of steam, which gives a trace like the noise trace in Figure 2 of the students' worksheets.

Students should be familiar with the representation of a wave motion as a displacement–time graph.



A prior demonstration of the modes of vibration of a string is helpful. Students may be interested to watch the vibrations when illuminated with a strobe lamp.



The effect of waveform on quality can be shown by listening to square, triangle and sine waves from a loudspeaker while watching them on a CRO screen.

Tone is used to describe quality or timbre. It can also be used to describe a musical interval, for example, a semitone, or the sound you hear when somebody plays a note.

The unit does not emphasize the distinction between the objective, measurable quantities of frequency and intensity, and the subjective, perceived quantities of pitch and loudness. This might be discussed with some students.

Part 2 Strings and wind

There are three terms used to describe the components of a vibration: harmonic, partial and overtone.

A **harmonic** must have a frequency that is an integral number of times the frequency of the fundamental. That number is the number of the harmonic.

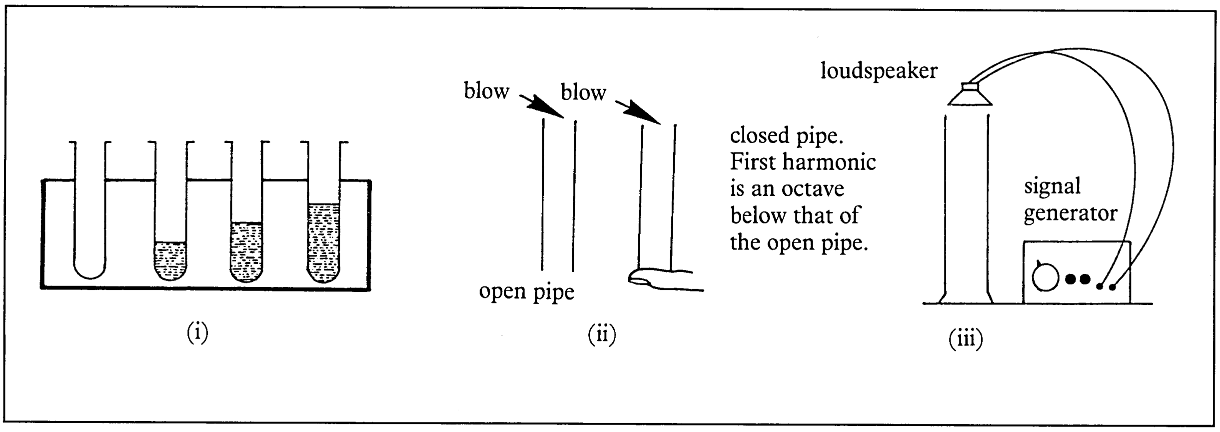
Partial is the name given to each component of a wave. Partials may, or may not, be harmonics and they are numbered in sequence from the lowest frequency. Some of the partials for bells are not harmonics.

An **overtone** is a component higher than the fundamental and is numbered in sequence from the lowest frequency. Overtones are not necessarily harmonics.

If a clarinet is overblown to produce a note an octave plus a fifth above its fundamental, this is the *first* overtone (that is the first component above the fundamental), the *second* partial (the fundamental being the first) but it is the *third* harmonic (because its frequency is three times that of the fundamental).

In the unit the only term used is 'harmonic' but students may meet the other words in physics or music textbooks.

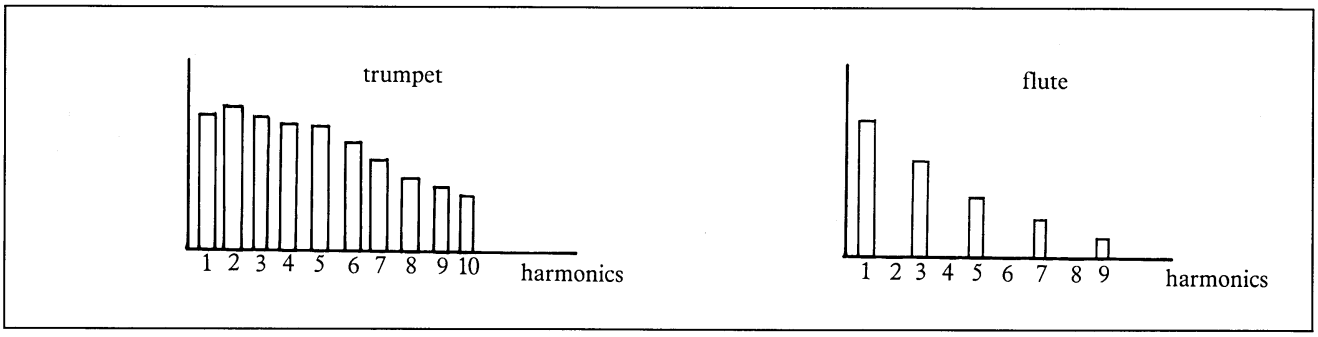
Students who have not encountered simple experiments on 'music' may enjoy (i) making a test-tube organ (and playing it by blowing across the top of the test tubes), (ii) investigating closed and open pipes by blowing a thermometer case, (iii) investigating the resonant frequencies of a measuring cylinder.



Part 3 Synthesizers

The advent of microchip technology has produced a surge of interest in the synthesis of speech and musical sounds. Early attempts based on textbook physics were very disappointing. It was soon discovered that synthesizing a sound was not merely a matter of specifying pitch, duration and a number of harmonics.

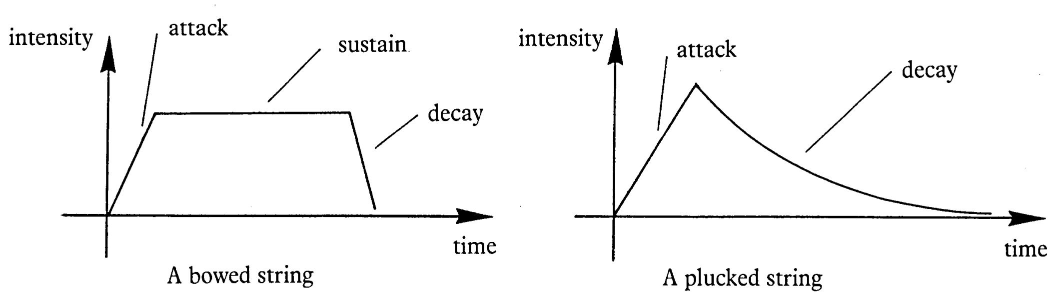
The study of musical notes with a spectrum analyser has revealed that tone depends on both the number and the intensity of the harmonics which sound. Low notes from open pipes (like brass instruments) are rich in harmonics in the audible range, while higher ones have fewer which can be heard. Harmonics may interact with each other so that some build up while others decay, causing the timbres to change as the note sounds. This is easily heard when a note on a piano is played.



Musical notes have beginnings, middles and ends characteristic of each instrument. They can be compared by studying the intensity envelope of the sound.

The science of musical sound is now well understood. Any sound can be synthesized and new ones invented. The BBC radiophonic workshop and composers like Jean Michel Jarre have used this technology to create new kinds of musical sounds.

The loudness of a musical note is not uniform for its duration. The way it builds up and decays is a characteristic of each instrument. The sound envelopes produced by most musical instruments have three parts, attack, sustain and decay. If a string is plucked, its envelope has attack and decay phases only.



Synthesizers such as the Yamaha DX7 have an envelope divided into four parts, attack, decay, sustain and release.

It is possible to record musical sounds using a VELA or a Philip Harris Data Memory and play back through an oscilloscope. The 'attack' phase will be missed with automatic triggering of the recording. Manual triggering is a rather hit-and-miss affair, but with practice can produce worthwhile results. Musical students could investigate the effects of different techniques (for example, tonguing, embouchure, bowing) on the envelope of the waveform.

The attack phenomenon results from the inertia of the vibrating system. A tuning fork struck and then placed on a table cannot make the table jump instantly into vibration. Similarly a reed cannot start a vibration in a column of air immediately. The inertia of the system leads to the relatively slow build up during the attack phase.

Answers to selected questions

Q. 9 (a) recorder, (b) flute, (c) clarinet, oboe, etc. (d) trumpet, trombone, etc.
Q.10 The player has to set his/her lip tension in advance.
Q.11 If $f_1 = 110$, $f_2 = 220$, $f_3 = 330$, $f_4 = 440$, $f_5 = 550$

on the piano: A, A, E, A, C#*

* C# on the piano is sharp because of equal tempering. C# is 554 Hz while the fifth harmonic is 550 Hz. Brass players have to 'lip up' the fifth harmonic to sharpen it.

References

Freeman, Ira, M., *All about Sound and Ultrasonics.* W.H. Allen, 1967.

Mathews, Max V. and Pierce, Hon R., 'The computer as a musical instrument', *Scientific American,* February 1987.

The Physics of Music. Readings from *Scientific American* with introduction by Carleen Maley Hutchins. W.H. Freeman, Oxford, 1978.

Pierce, John R., *The Science of Musical Sound.* W.H. Freeman, Oxford, 1984.

Taylor, C.A., *Sounds of Music.* BBC Publications, 1976.

Acknowlegements Figure 1 supplied by the Photographic Unit, ILEA Television and Publishing Centre; Figure 8 supplied by Dr. B.E. Richardson, Department of Physics, University College, Cardiff.

WHAT ARE THE SOUNDS OF MUSIC?

Why may one person's music be another person's noise? Why do musical instruments sound different even when they are playing the same note? How can an electronic keyboard play notes which are similar to those made by other musical instruments? These are some of the questions for you to think about as you study this unit.

Figure 1

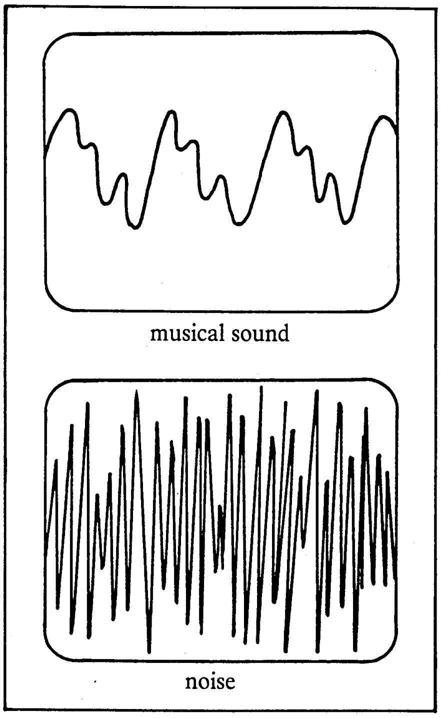


Figure 2

Part 1 Music or noise?

A jet engine and a clarinet both produce sounds. You would probably call the sound from the jet engine 'noise' and the sound from the clarinet 'music'. Noises are sounds which we find unpleasant.

Sometimes an oscilloscope shows a clear difference between music and noise. Figure 2 gives examples of what you see on the screen with a musical sound and with noise. You can see that the musical sound has a regular *waveform.* (You can do this for yourself if you try Investigation 1 in Part 4.)

The difference between noise and music is not always so clear. Someone who cannot play the violin makes a 'noise', while a trained musician produces the regular waveforms of 'music'. It also depends on personal taste. The sound of a rock band may be 'music' to teenagers but 'noise' to their parents.

Your own taste depends on what waveforms you have learned to understand. Many teenagers listen to rock bands regularly and recognise the waveforms. Their parents are often less familiar with these sounds.

Chinese pop tunes do not reach the charts in England. They sound strange to our ears. The reason is the same, most of us cannot recognise the regular patterns of the sounds. The waveforms are unfamiliar.

Now answer questions 1 to 3.

Questions

1 *Which of these sounds are 'noise' and which are 'music':*
  (a) a jet aircraft taking off
  (b) a symphony orchestra playing Mozart
  (c) heavy lorries on the motorway
  (d) the signature tune to 'Coronation Street'?
  Does everyone in your class agree on the answers?

2 *In what ways is the waveform for music different from that for noise in Figure 2?*
  Why do people find noise unpleasant?

3 *How would you classify these sounds? What do you need to know about the performers before you can be sure?*
  (a) somebody playing a violin
  (b) a rock band.
  How might your grandparents classify them?

Waveforms

You are probably not aware of the amazing way that your ear and brain can sort out different sounds.

Every time you enjoy music you are responding to many complex waveforms at the same time. Even one note on a piano has a waveform made from many waves combined together. The waveform actually changes as the note sounds. Imagine what your brain has to cope with when you listen to several instruments together.

A French mathematician called Jean Baptiste Fourier (1768-1830) made the discovery that a complicated wave can be produced by adding together simple waves. The simple waves are called harmonics. Figure 3 shows the four harmonics which are combined in the note from a piano.

Properties of musical notes

Pitch is the term musicians use to describe how high or low a sound seems to be. Scientists measure the pitch of a note by the frequency of its sound wave.

Loudness is related to the amount of power per square metre reaching the ear. This depends on the amplitude of the sound wave. The greater the amplitude, the louder the sound.

Tone or **timbre** is the quality of the note. Notes from different musical instruments may have the same pitch and loudness but still sound different. This is because they are made up of a different mixture of waveforms. Musicians use words like *rich, thin, harsh, clear* and *warm* to describe different timbres.

Now answer questions 4 and 5.

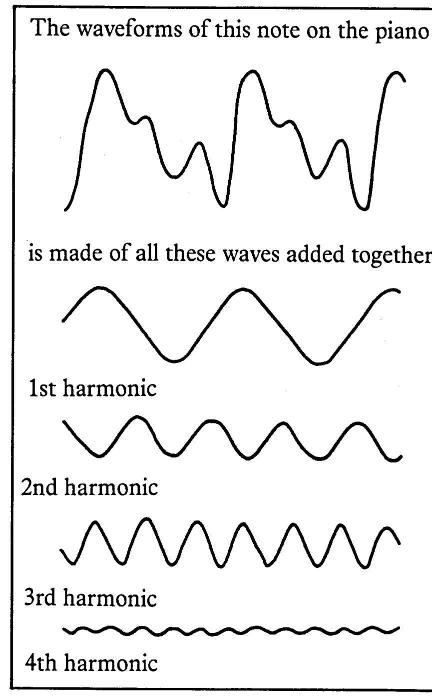


Figure 3

Questions

4 *Look at the waveforms produced by tuning forks S and T in Figure 4.*
(a) Which note has the shorter wavelength?
(b) Which note would sound higher in pitch?
(c) Which tuning fork is vibrating with the higher frequency?
(d) Which is the smaller tuning fork?

5 *Look at the kinds of waveforms produced by a violin, flute and French horn in Figure 4.*
(a) Do they have the same wavelength?
(b) Are they playing a note of the same pitch or frequency?
(c) Suppose all three instruments play the same note. You can hear the difference because their sounds differ in tone. How could you deduce this from the trace on the oscilloscope screen?

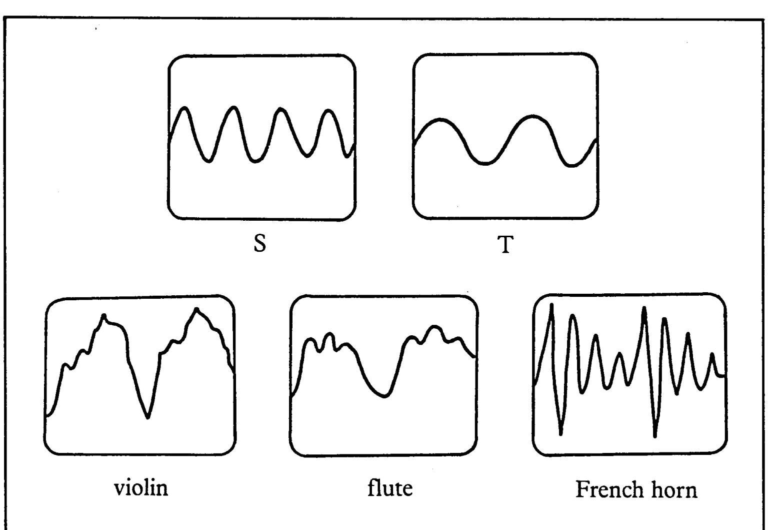


Figure 4 The time base of the oscilloscope was kept constant so that it was always scanning at the same rate

Part 2 Strings and wind

Stringed instruments

Stringed instruments (such as the guitar, harp, piano and violin) produce a sound when you make the strings vibrate by plucking, hitting or bowing them.

The **pitch** of the note you hear depends on the *length* of the string, its *tension* and the *mass per unit length.*

Figure 7 shows how the string of an instrument can move when a note sounds. Each harmonic is a different mode of vibration. In Figure 7 you see a family of harmonics called a **harmonic series.**

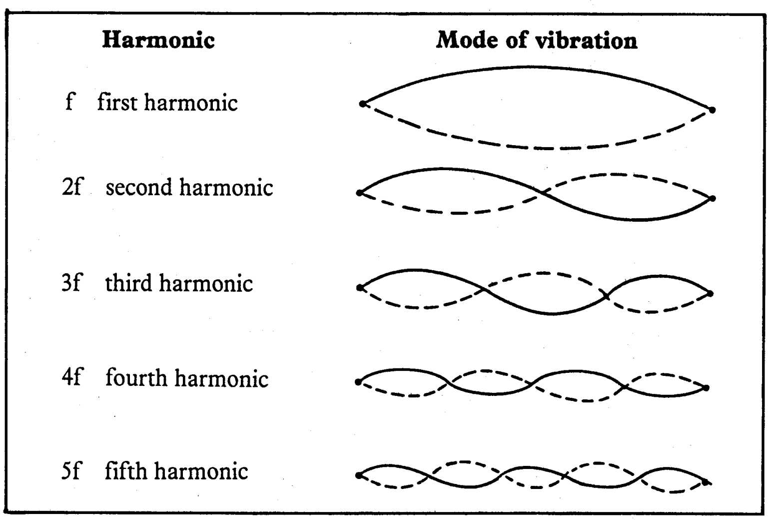


Figure 7 The modes of vibration of a string

The wave on a string does not move along the wire like a wave on water. The wave stays in one place as each part of the string vibrates.

If you watch a vibrating string you can see that its movement is complex. It is a combination of harmonics. Strings can vibrate only at frequencies which are two, three, or more times the frequency of the simplest vibration. The combination of all these modes of vibration gives the sound its tone.

Amplifying the sound

A single vibrating string gives little sound because it moves a very small volume of air. The vibrations of strings on electric guitars are amplified electronically. The signal from the amplifier has the power to allow the loudspeakers to make more air vibrate.

On most stringed instruments, sound is amplified 'acoustically' by a sound box. The string forces the sound box to vibrate. This sets a much larger volume of air into vibration. The shape and structure of the sound box affects the way it vibrates and helps to produce the characteristic tone of the instrument.

Now answer questions 6 to 8.

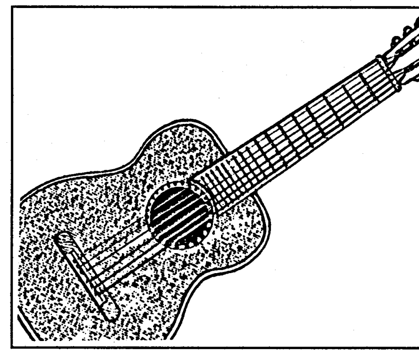


Figure 5 A guitar

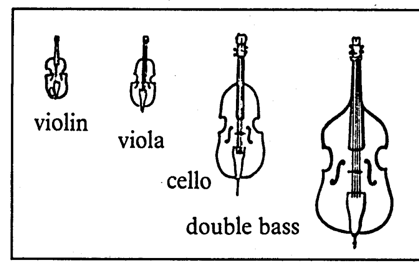


Figure 6 A family of string instruments

Questions

6 *Name* one *instrument in which the strings are set vibrating by:*
(a) plucking
(b) bowing
(c) hitting.

7 *Cello, double bass, viola and violin are members of a family of instruments with the same shape.*
(a) Which gives the highest notes and has the shortest strings?
(b) Which gives the lowest notes. Why?
(c) How can a player change the pitch of a note?
(d) These instruments all produce a similar tone. Why?

8 *(a) How does a guitarist change*
(i) the length,
(ii) the tension of a string?
(b) How can guitar strings be made with different values for the mass per unit length*?*

Wind instruments

Wind instruments include the clarinet, flute, recorder and trumpet. They produce a sound when the air inside them is made to vibrate. A woodwind player blows over a reed, a hole or a sharp edge. Brass players set up a vibration by making their lips vibrate.

If you have tried to play a flute or a trumpet you will know that you need to practise to produce a sound at all. Even reeds are difficult to coax into vibration and need sucking to soften them.

The air in a pipe has modes of vibration giving a set of notes called the harmonic series. This is very similar to the vibrations of strings.

Simple trumpets are just brass tubes with no holes or valves. They can sound only the notes produced by the harmonic series. The modern trumpet can play all the notes of the scale by using valves to divert the air through three extra lengths of tubing. This increases the length of the instrument so as to lower the pitch by a definite amount.

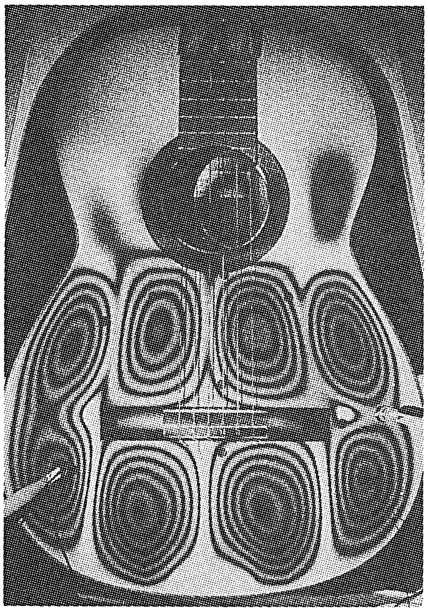


Figure 8 The mode of vibration of a guitar at 1010Hz. The vibrations were made visible by holographic interferometry

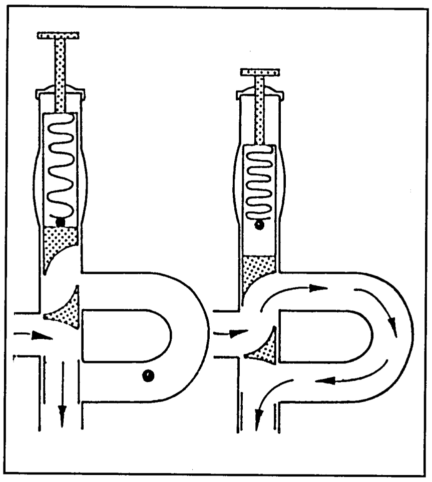


Figure 9 A trumpet valve — closed and open

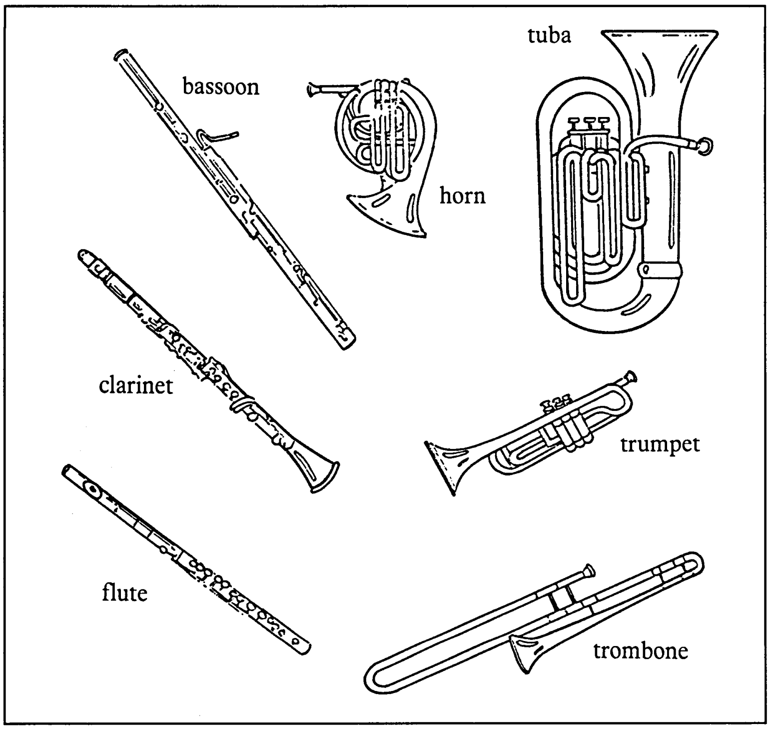


Figure 10 Wind and brass instruments

The longer the column of air, the lower the frequency at which it vibrates. So the longest wind instruments produce the lowest notes. There are whole families of instruments which show this pattern.

On a woodwind instrument you open or close some of the holes to play different notes. This has the effect of changing the length of the air column inside. Modern woodwind instruments, like the clarinet, have keys which open and close holes that are too far away to reach easily.

Now answer questions 9 and 10.

Questions

9 *Give examples of wind instruments where the air is set into vibration by blowing:*
(a) over a sharp edge
(b) across a hole
(c) over a reed
(d) through tightened lips.

10 *Why do you think brass players find it so difficult to 'pitch in' and play the first note at the correct pitch?*

Part 3 Synthesizers

Almost all pop groups use a synthesizer. It can generate notes of any pitch, tone and loudness by controlling a system of oscillators which produce electrical vibrations.

One oscillator is tuned to the first harmonic and this gives the note its pitch. The other oscillators are set to give higher harmonics to make the tone richer. Sometimes an oscillator is set slightly out of tune to give a vibrato effect.

The loudness of a note is more complicated. It always takes a little time for the sound of a note to build up. It may then be sustained or gradually die away. When a violin is played with a bow the sound is sustained. When the string is plucked the sound gradually dies away. A typical 'envelope' for the loudness of a note on a synthesizer consists of four parts, attack, decay, sustain and release (Figure 12).

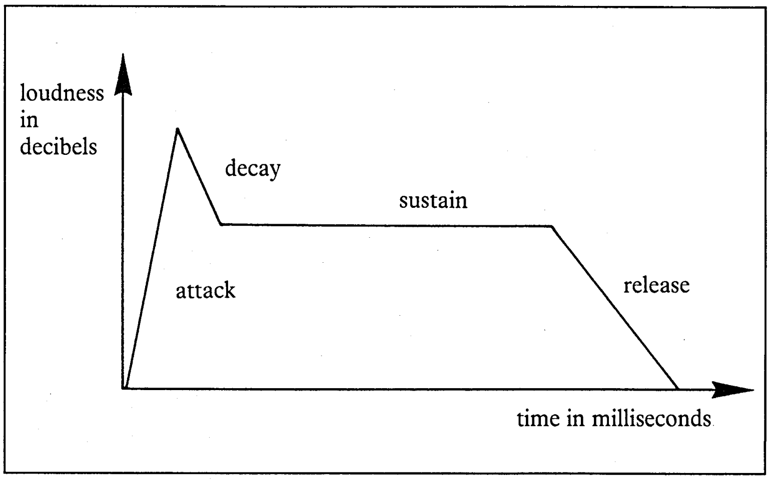


Figure 12 A typical envelope for a synthesizer note

Rich sounds can be synthesized by adding waveforms but many oscillators and complex circuits are needed to control them all. In practice, synthesizers use frequency modulation (FM) to produce a similar result with fewer oscillators.

Now answer questions 11 to 13.

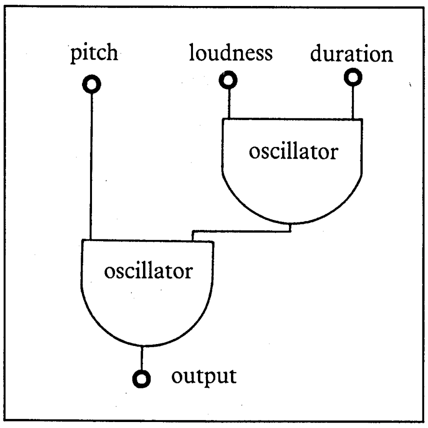
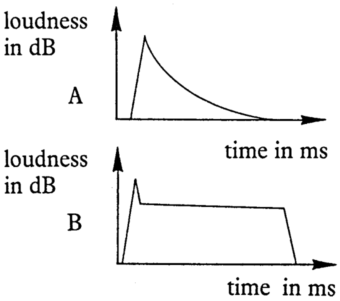


Figure 11 A simple synthesizer

Questions

11 Calculate the first five harmonics of a note of frequency 110Hz. What are these notes on the piano? (See Figure 13.)

12 Which envelope (A or B) could be the sound of a bowed string and which a plucked string?



13 Do you think that synthesizers could eventually replace ordinary musical instruments? Give reasons for your opinion.

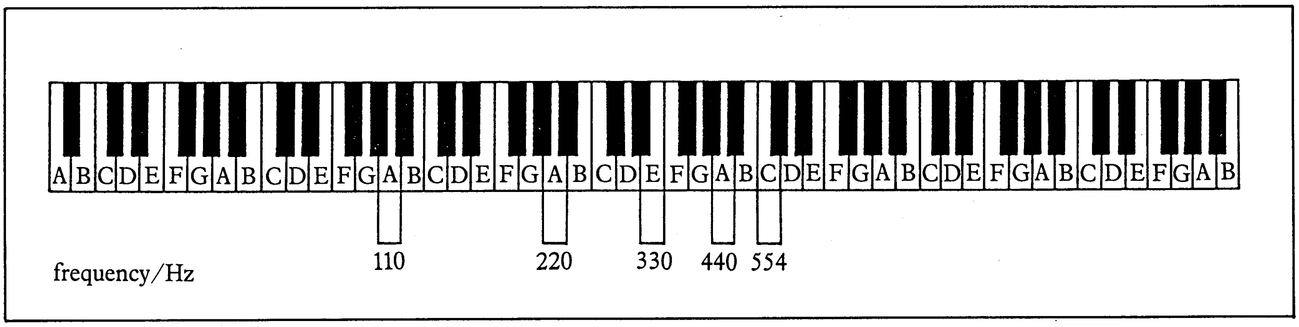


Figure 13 A keyboard showing the frequencies of some notes

Part 4 Investigations

A Looking at waveforms

Use a microphone and oscilloscope to study the pitch, loudness and tone of musical notes from various instruments. Compare the notes from a single musical instrument with the same note from the loudspeaker of an electronic keyboard.

(Remember that sound waves are longitudinal. They make the diaphragm in the microphone vibrate backwards and forwards. The movement of the diaphragm produces an electrical signal which is displayed on the oscilloscope. You are looking at a displacement–time graph on the screen.)

B Sounding the harmonics

If you have a stringed instrument such as a guitar available, you can try to sound the harmonics. Just plucking the string gives mostly the first harmonic. To sound the second harmonic, touch the string at its mid point and pluck it (Figure 14). The string will vibrate in two halves. The second harmonic is an octave above the first. The third harmonic is quieter but you can sound it by touching the string at one third of its length and plucking it on either side.

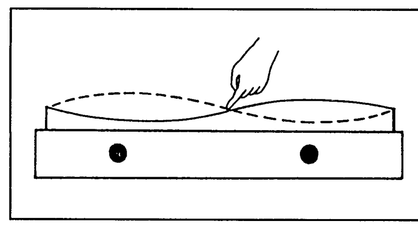


Figure 14

C Playing a hose-pipe trumpet

You can make a hose-pipe trumpet from 3.5m of garden hose, a plastic funnel and a mouthpiece from a brass instrument (Figure 15). The length of this instrument is about the same as a French horn.

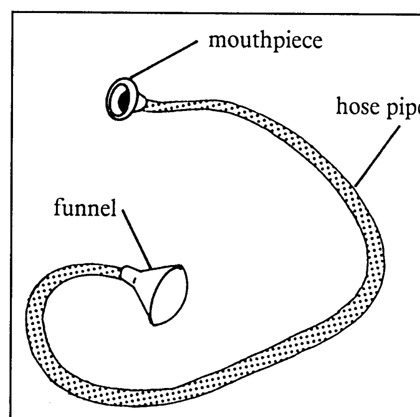


Figure 15

To play a brass instrument you need to pucker your lips (do not put your tongue between them) and blow a 'raspberry' to make them vibrate.

Find the lowest note you can play and then by tightening your lips you can increase their frequency of vibration to play higher notes. The notes you get will be those in the harmonic series, not every note in the scale. Try playing with and without the funnel to find out why most instruments have bell-shaped ends.

D Synthesizing a musical sound

Set a signal generator to 110 Hz and connect it to a loudspeaker. The note you hear is boring because there are no harmonics sounding at the same time and it has no definite beginning or end. Try tuning a second signal generator and loudspeaker to the second, third, fourth and fifth harmonics. The tone of combined sounds will be better. (With a third signal generator and speaker the sound of three harmonics together is richer still.)

To produce a vibrato effect, tune two signal generators to the same frequency, say 110 Hz, and then alter one of them slightly. The two sounds will seem to vibrate or 'beat' together.